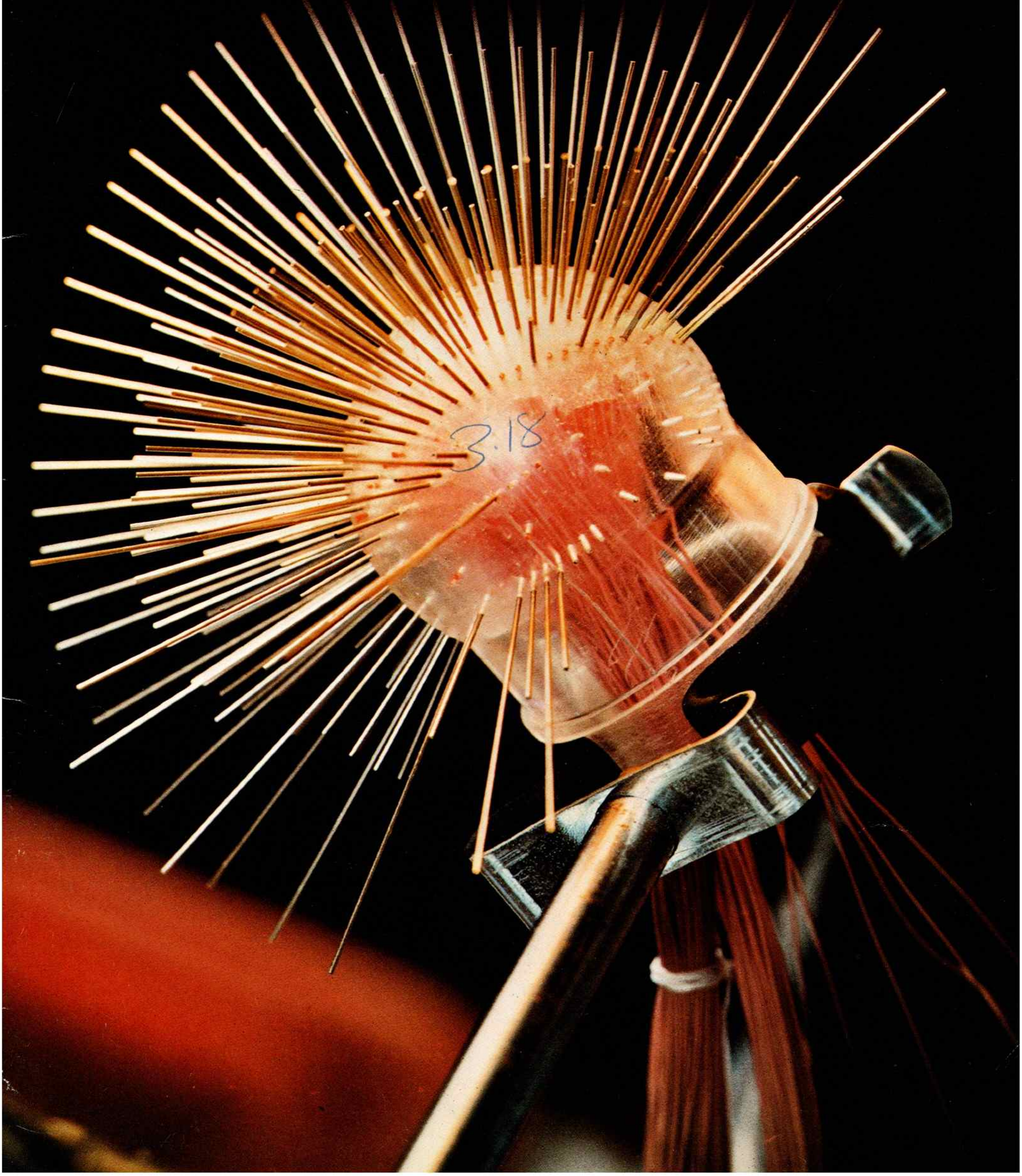
AWRE

Atomic Weapons Research Establishment



Underwater test launch of Chevaline

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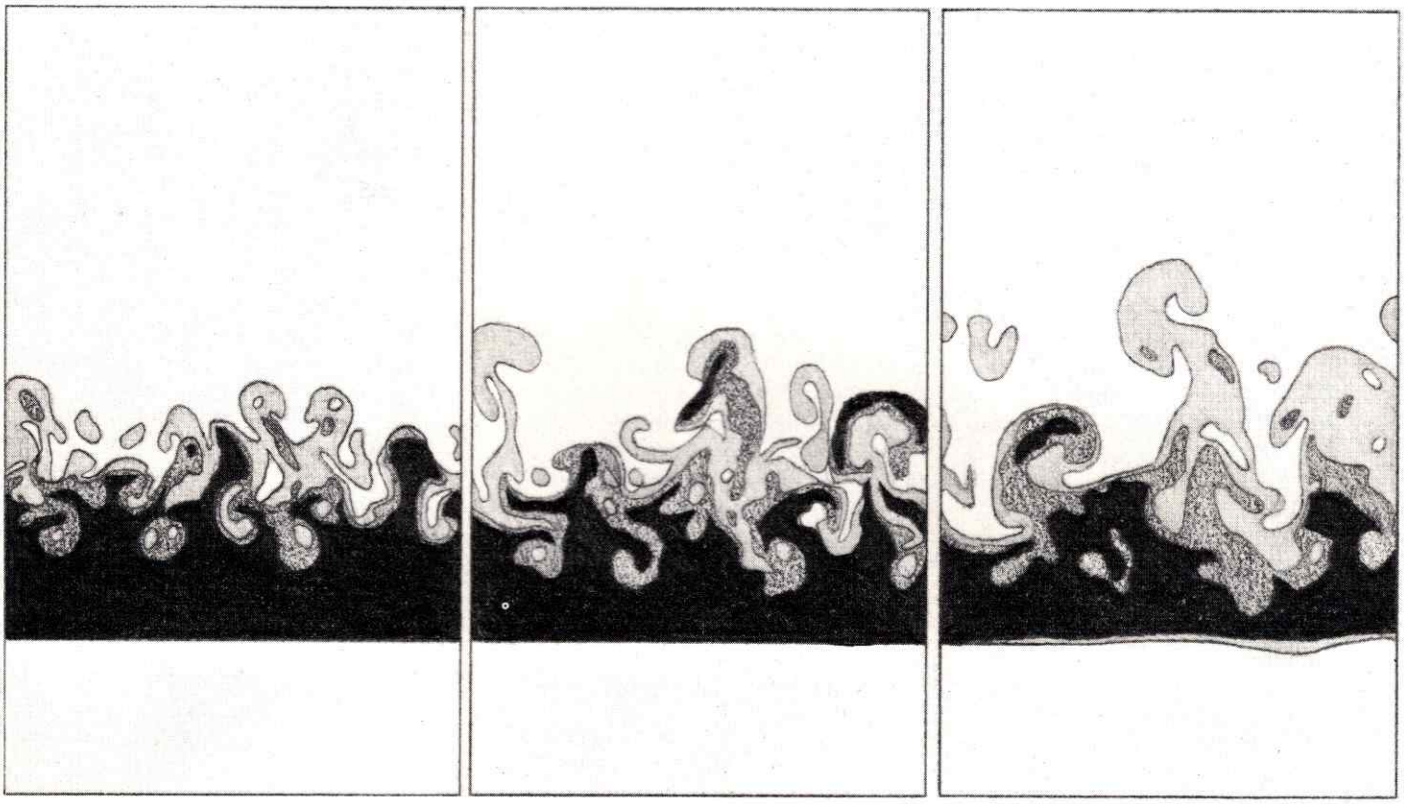


Contents

AWRE – the short title by which it is familiarly known – is a research and development establishment administered by the Procurement Executive of the Ministry of Defence and has a basic function to design and develop the nuclear warheads essential to Britain's nuclear deterrent capability. An important aspect of this function is the collaboration with the United States under the 1958 Agreement on 'The Uses of Atomic Energy for Mutual Defence Purposes.'

In addition to its major role the establishment also contributes to some non-nuclear defence projects, and where its unique facilities are vital a limited amount of civil work is also undertaken.

Since the Second World War Britain has made an important contribution to the development of nuclear science and nuclear engineering. Military research was a forerunner in these modern fields of technology which have made a vital contribution to Western defence in the past three decades.

Being concerned with some of the nation's most closely guarded secrets, the depth and extent of this military programme tends to be obscured but it is always at the advancing fringes of scientific knowledge and the frontiers of developing technology. It is concentrated at the Atomic Weapons Research Establishment which, with its assembly of some of the finest, and often unique, scientific facilities and a multi-disciplinary talent of outstanding breadth, has earned international repute. Its success depends on the contribution of all the staff in a wide variety of grades, both industrial and non industrial.

The disciplines located at Aldermaston and Foulness are described in this brochure grouped as Design, Development and Materials. Services to these groups and to the establishment as a whole are provided by Engineering, Safety and Administration.

The Role

The British nuclear weapons programme began in 1947 under the leadership of Dr William Penney (now Lord Penney), who was among a team of British scientists associated with the development of the first atomic bombs in the United States during the Second World War. The enterprise was initially co-located at the Armament Research and Development Establishment at Fort Halstead, in Kent, and an out-station at Woolwich Arsenal. Later there were other out-stations at Woolwich Common for weapon electronics production and at Orfordness in Suffolk for the environmental testing of warhead explosive assemblies.

In the early 1950s the work was progressively transferred to the extensive site at Aldermaston, which was being developed as a permanent base for the programme and, at about that time, an open range was established at Foulness Island in the Thames estuary, near Southend-on-Sea, as an out-station for experimentation with chemical high explosive assemblies.

Today AWRE houses a large staff of scientists, technologists and supporting categories in complexes of purpose-built laboratories, workshops and offices at Aldermaston and at its Foulness out-station. A small group operate from Blacknest near Aldermaston, where seismological studies are undertaken.

The available facilities are of the highest scientific standards with apparatus and equipment being generally sophisticated, uncommon or unique and with much of it developed and engineered within the establishment for highly specialised purposes.

The overall task may be divided into nuclear and non-nuclear work.

Nuclear

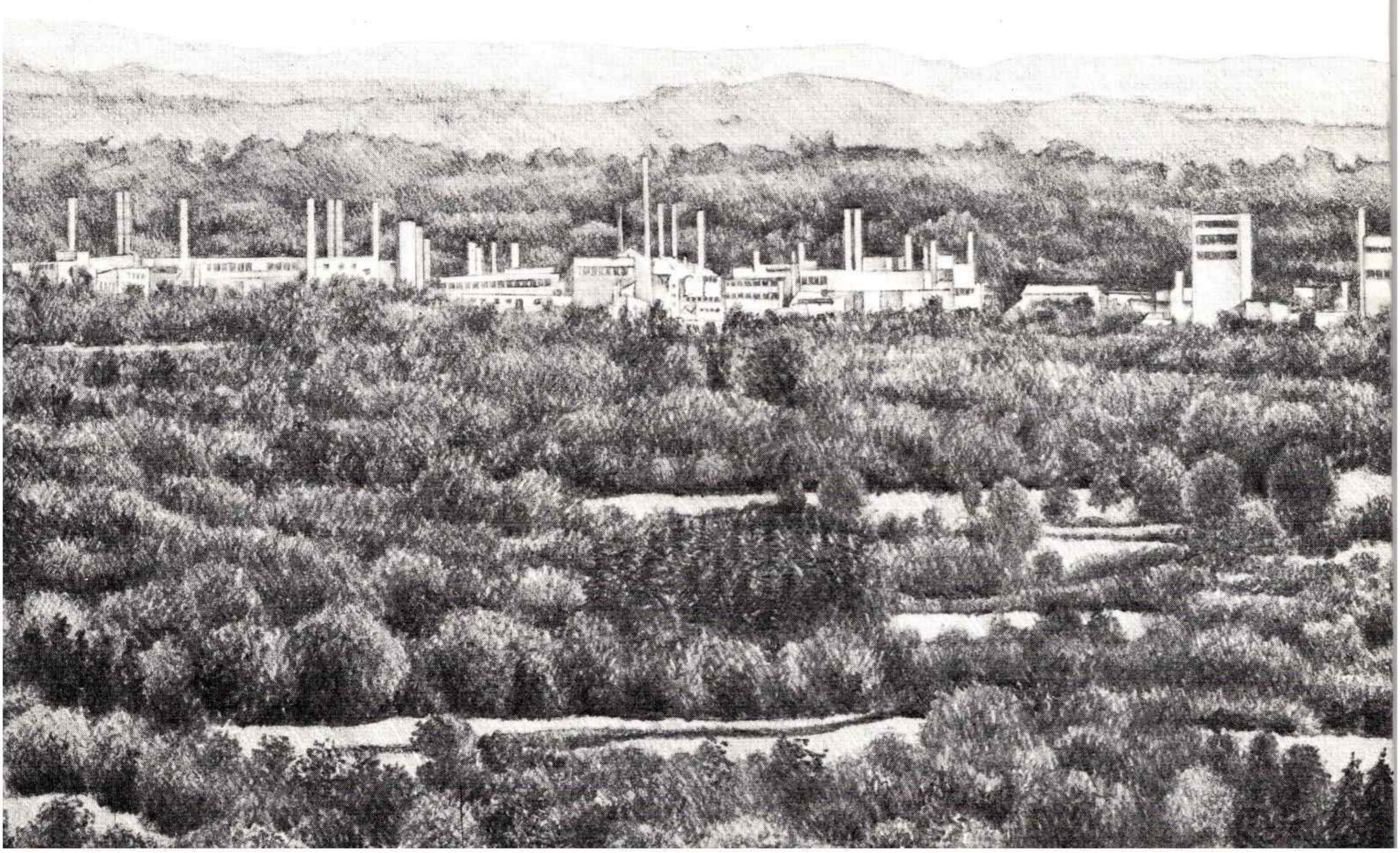
This is the main programme and is primarily concerned with the design and development of warheads for strategic and tactical nuclear weapons to maintain the effectiveness of the British nuclear deterrent. This includes responsibility for the warheads of the weapons of the Royal Navy's nuclear missile carrying Submarine Fleet.

Some of the major parts of the programme are:

* post design support for the servicing of nuclear warheads
* research and development to explore the potentialities of future technologies
* the research and development of a wide range of materials, including chemical high explosives
* the development of techniques for the detection and identification of both atmospheric and underground nuclear explosions for the purpose of monitoring compliance by states that are signatories to certain Nuclear Test Ban Treaties
* the evaluation of nuclear weapon effects on military targets and equipment
* research and development in connection with radiological defence
* collaboration with the United States government under the agreement on the 'Uses of Atomic Energy for Mutual Defence Purposes'.

Non-Nuclear

One responsibility is the employment of special expertise in theoretical and experimental shock physics for application in the general area of non-nuclear weapon performance, an example being the study of armour penetration. AWRE is now



responsible for all MOD(PE) research into chemical explosives with emphasis on power and safety. Assistance is also given to the Royal Armament Research and Development Establishment in the development of bombs for specific purposes using techniques of AWRE origin.

The capability of AWRE
These programmes call for expertise in classical and modern physics, chemistry, materials science, mathematics, electronics and various branches of engineering.

The work ranges from long-term fundamental research, through the development of technology, design, the prototype development of novel systems and the environmental testing of engineered products.

Critical demands are made in nuclear weapon design for stability, strength, safety and compactness. This calls for ingenuity and a high degree of accuracy in materials research where the emphasis is on the three recognised nuclear metals, plutonium, uranium and beryllium, on high explosives and on a wide variety of inorganic and organic artefacts e.g. rubbers, plastics, etc. For its research and development of beryllium technology, AWRE has earned an international reputation.

AWRE research also studies the physics of the earth's crust in aid of seismic systems for detecting underground nuclear explosions and discriminating them from natural events.

The difficulties of monitoring underground nuclear explosions contributed to the exclusion of underground tests from the Test Ban Treaty in 1963. Since then, however, programmes of research to overcome these difficulties have been undertaken in the United Kingdom at AWRE,* and at United States research establishments leading to a considerable advance in the study of the science of seismology.

In support of the integral facilities of laboratories and workshops there is a variety of supporting services including: a well-stocked technical library, information services, an extensive computer service (the largest of its kind in Britain) including a site-wide multi-access terminal link system, and a Drawing Office.

There are also reactor research facilities to assist in studying the effects of radiation on materials and electronic components. There are two reactors. Herald, the most powerful light-water research reactor in the United Kingdom, is used for neutron activation analysis, for measuring the effects of nuclear radiation on materials and for studying the structure of materials by means of neutron scattering. It is a 5 MW intense source of neutron and gamma radiation and is used by university research teams and other research establishments as well as by AWRE staff.

The second reactor, Viper, is the only one of its kind in Europe. It is a fast-pulsed reactor designed to produce very intense short duration pulses of neutrons and gamma rays with a peak power of 20,000 MW. At present it is being used for many research programmes aimed at the better understanding of the effects of radiation on fissile and non-fissile materials and electronic components.

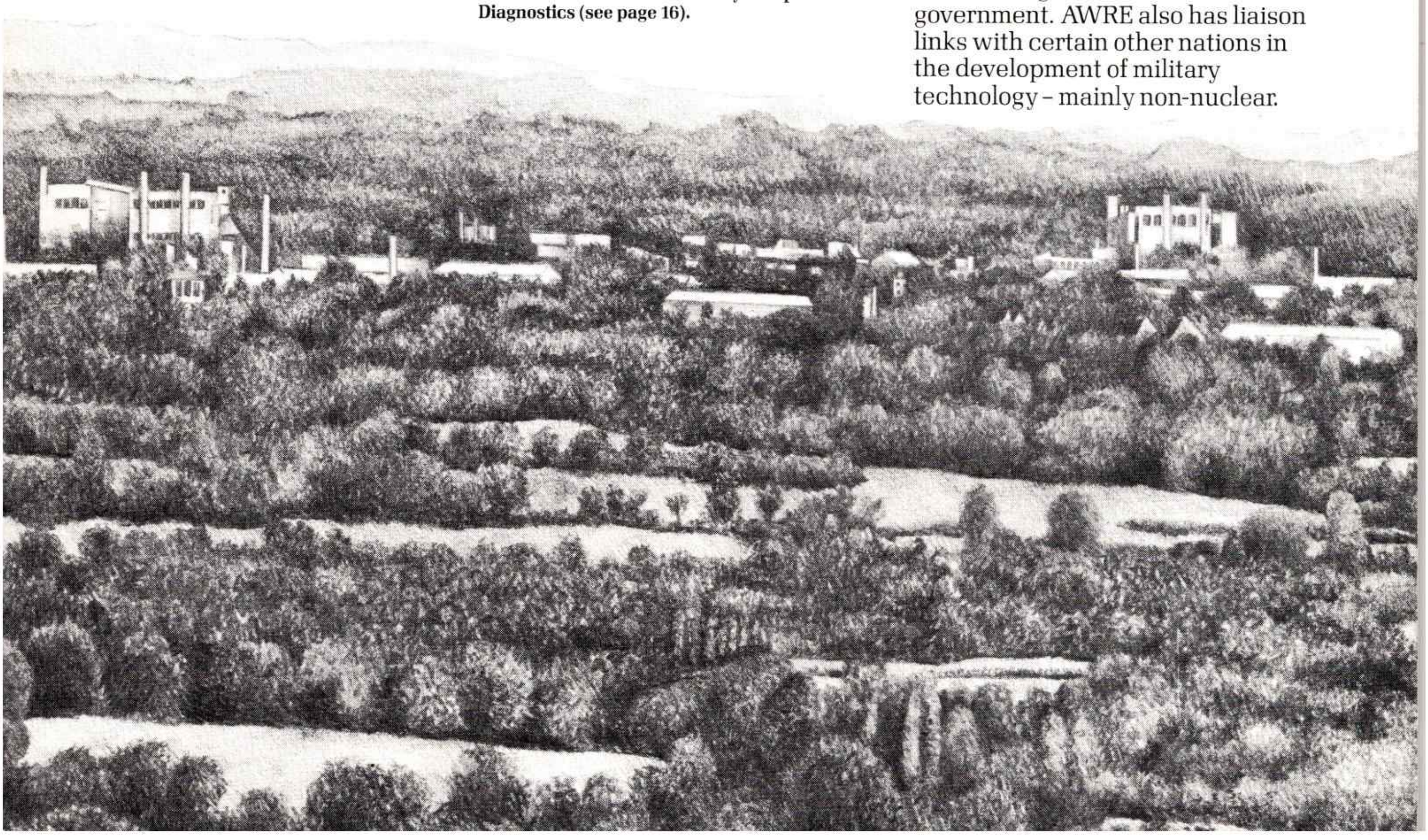
More recently the one terawatt HELEN laser facility has been installed to investigate the behaviour of very small targets, by subjecting them to temperatures and pressures which are experienced in a nuclear explosion.

In the continuing policy of providing the most up to date facilities, a new building is under construction for the processing of plutonium. This will contain many novel features and the most advanced handling techniques to achieve the highest standards of radiological safety.

Test facilities have been developed to confirm the structural integrity of the weapon system by subjecting prototypes to stresses of temperature, shock and vibration over a wide range of environmental conditions.

International Co-operation
As nuclear partners within the North Atlantic Treaty Organisation, there is a large measure of co-operation between Britain and America. This has included advice and counsel given by nuclear scientists of AWRE to various technical agencies of the US government. AWRE also has liaison links with certain other nations in the development of military technology – mainly non-nuclear.

***This research is undertaken by Weapon Diagnostics (see page 16).**



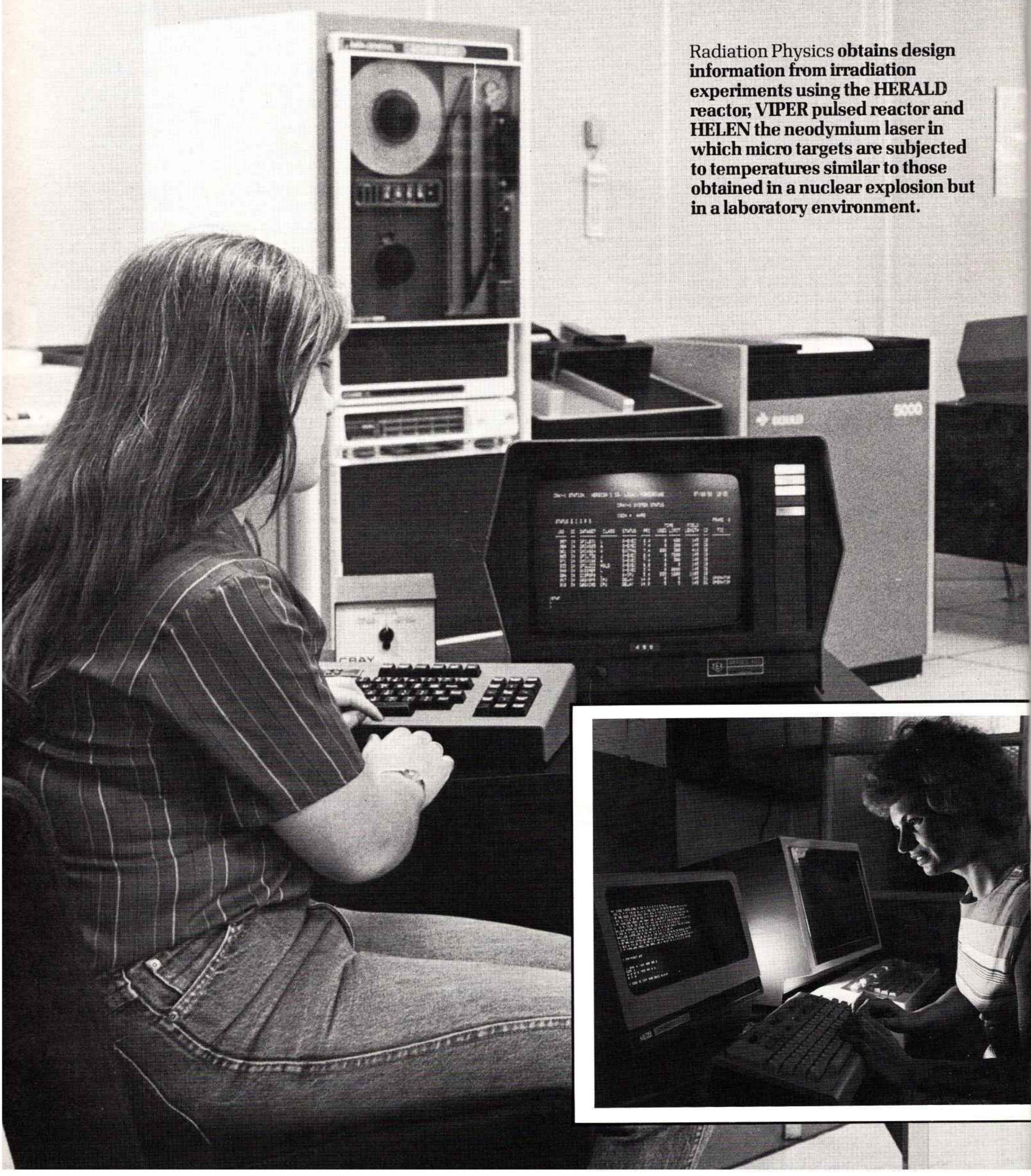
Design Physics for

The Divisions of the establishment in the following three sections are concerned with the physics of the design:

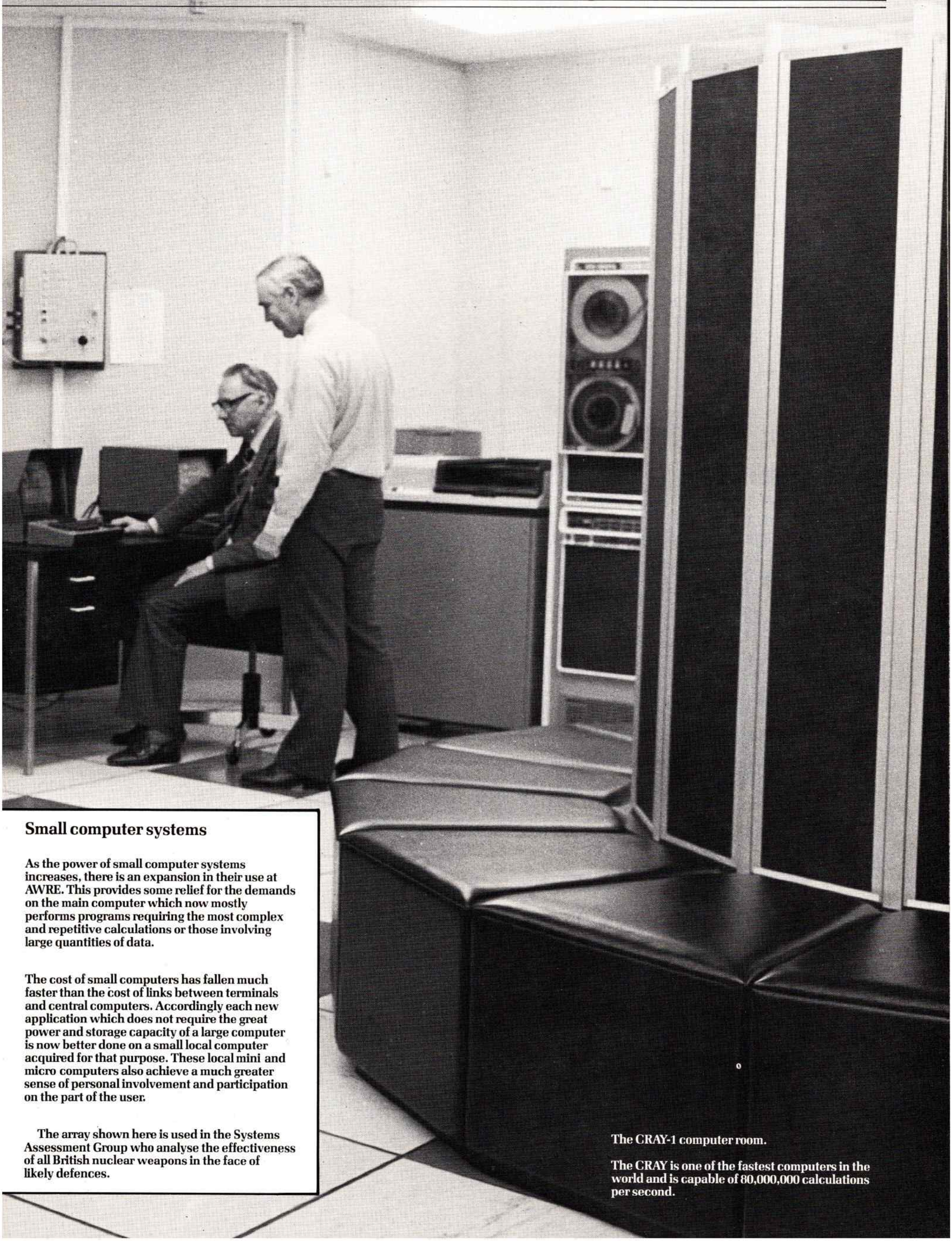
Mathematical Physics **studies include aspects of plasma physics, neutron transport, fluid dynamics and the simulation of complex design experiments by modelling on the high power CRAY computer.**

Warhead Hydrodynamics **complements experimentally the theoretical fluid studies of Mathematical Physics, and operates equipment capable of delivering extremely high explosive shocks, monitored by sensors able to detect effects on nanosecond time scales.**

Radiation Physics **obtains design information from irradiation experiments using the HERALD reactor, VIPER pulsed reactor and HELEN the neodymium laser in which micro targets are subjected to temperatures similar to those obtained in a nuclear explosion but in a laboratory environment.**



Nuclear Weapons



Small computer systems

As the power of small computer systems increases, there is an expansion in their use at AWRE. This provides some relief for the demands on the main computer which now mostly performs programs requiring the most complex and repetitive calculations or those involving large quantities of data.

The cost of small computers has fallen much faster than the cost of links between terminals and central computers. Accordingly each new application which does not require the great power and storage capacity of a large computer is now better done on a small local computer acquired for that purpose. These local mini and micro computers also achieve a much greater sense of personal involvement and participation on the part of the user.

The array shown here is used in the Systems Assessment Group who analyse the effectiveness of all British nuclear weapons in the face of likely defences.

The CRAY-1 computer room.

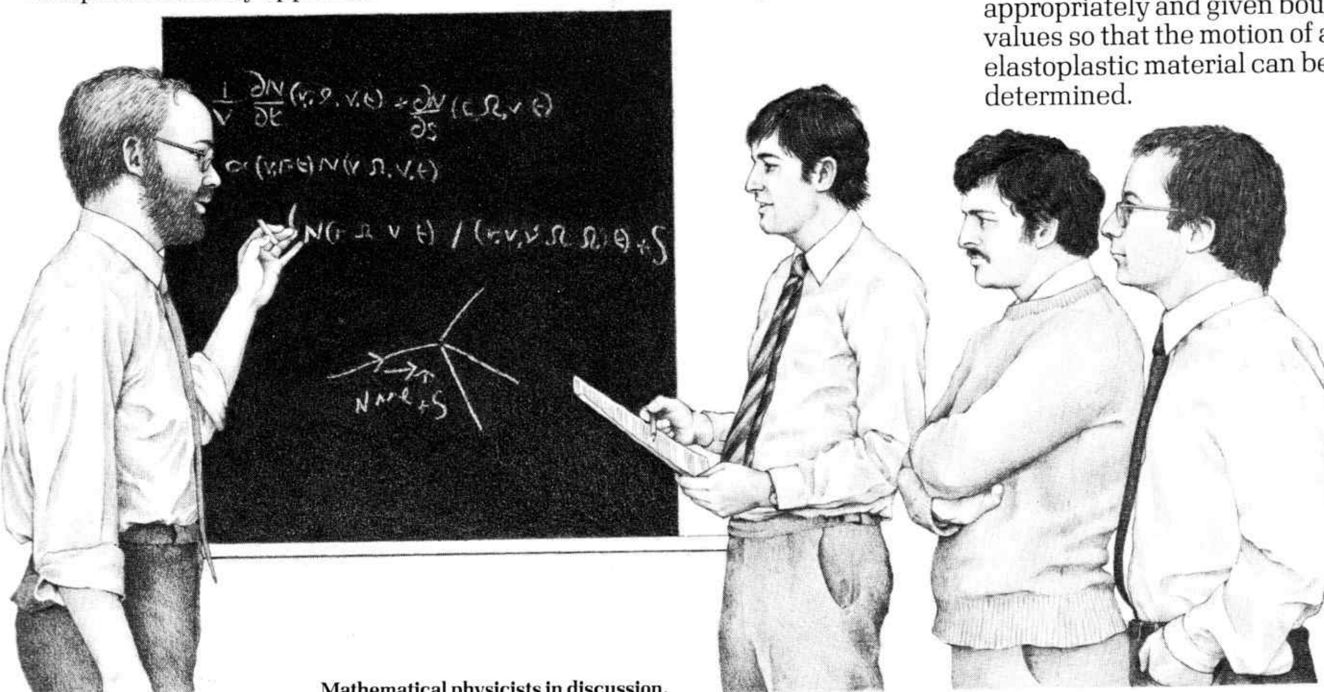
The CRAY is one of the fastest computers in the world and is capable of 80,000,000 calculations per second.

Mathematical Physics

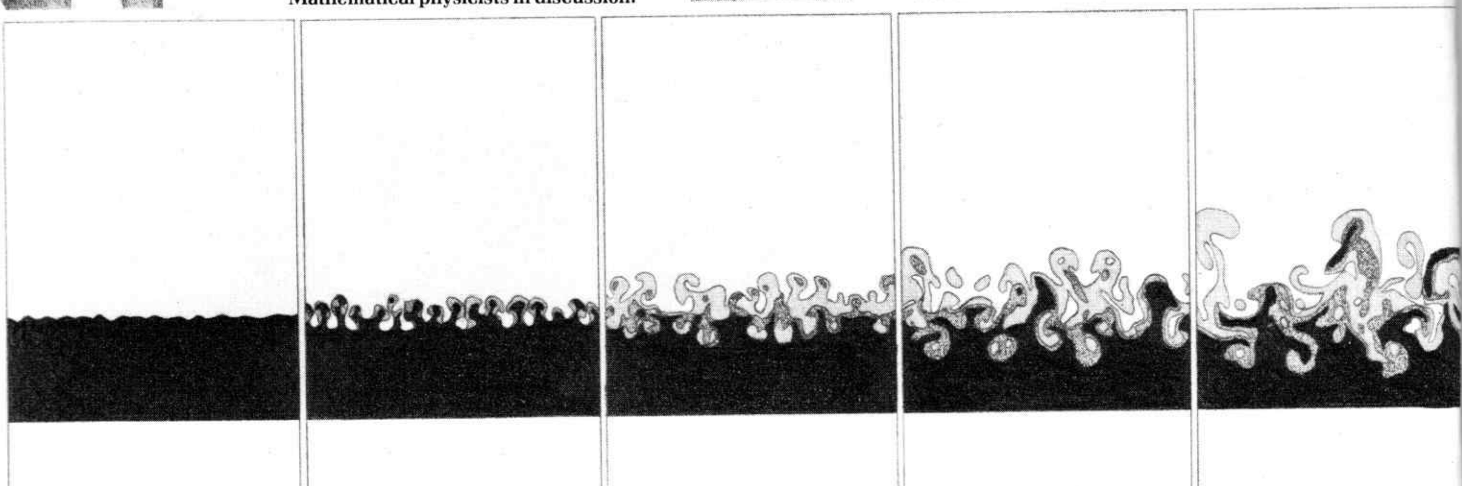
Theoretical Design
When a nuclear weapon begins to explode, temperatures and pressures within the weapon are far in excess of those which can be produced in a laboratory. The physics of phenomena occurring under such conditions must be derived from theory alone. The necessary understanding of a modern nuclear weapon is, therefore, dependent on pure theory to an exceptional extent and calls for sophisticated computer codes to study the relevant physics and to calculate the fluid motion, neutron and photon transport and thermonuclear reactions which occur during an explosion. AWRE is the only establishment in the United Kingdom with expertise in this field. High-power lasers developed for laser fusion studies now produce plasmas in which the temperatures and pressures may approach weapon values; the theoretical study of experimental observations on such plasmas is a recent step towards validation, on a microscale, of the theoretical methods used in weapon design.

Fluid Dynamics
To assess the performance of nuclear weapons, or even those involving only normal chemical explosives, the behaviour of materials being subjected to forces far in excess of yield strength and undergoing appreciable compressions must be predicted. This is a problem in compressible fluid dynamics. Equations governing the conservation of mass, momentum and energy for unsteady compressible fluid flow in one or more space dimensions are well established but their application in realistic geometries, particularly with complicated boundary conditions, is less well developed. Several approaches have been followed but finite difference methods are frequently used in both one and two dimensional unsteady flow. Such methods have been developed in both Langrangian and Eulerian frames of reference. The latter is particularly useful in computing flows suffering gross distortions such as the growth of Rayleigh-Taylor instabilities at an interface between two fluids.

If stress levels are relatively low, the shear strengths of the materials may have significant effects on the flow and the simple hydrodynamic approximation of perfect fluids becomes inadequate. In these cases stress is considered as the sum of an isotropic hydrodynamic pressure and a stress term which varies with direction. These can be linked appropriately and given boundary values so that the motion of a full elastoplastic material can be determined.



Mathematical physicists in discussion.



The main computer console.

Special Methods

At high temperature it is necessary to consider radiation energy and its interaction with compressible fluid flow. When fissile material is involved the migration and interaction of neutrons in the various materials is also taken into account. A complete calculation consequently may involve several interacting physical phenomena and become highly complicated and demanding of computer power.

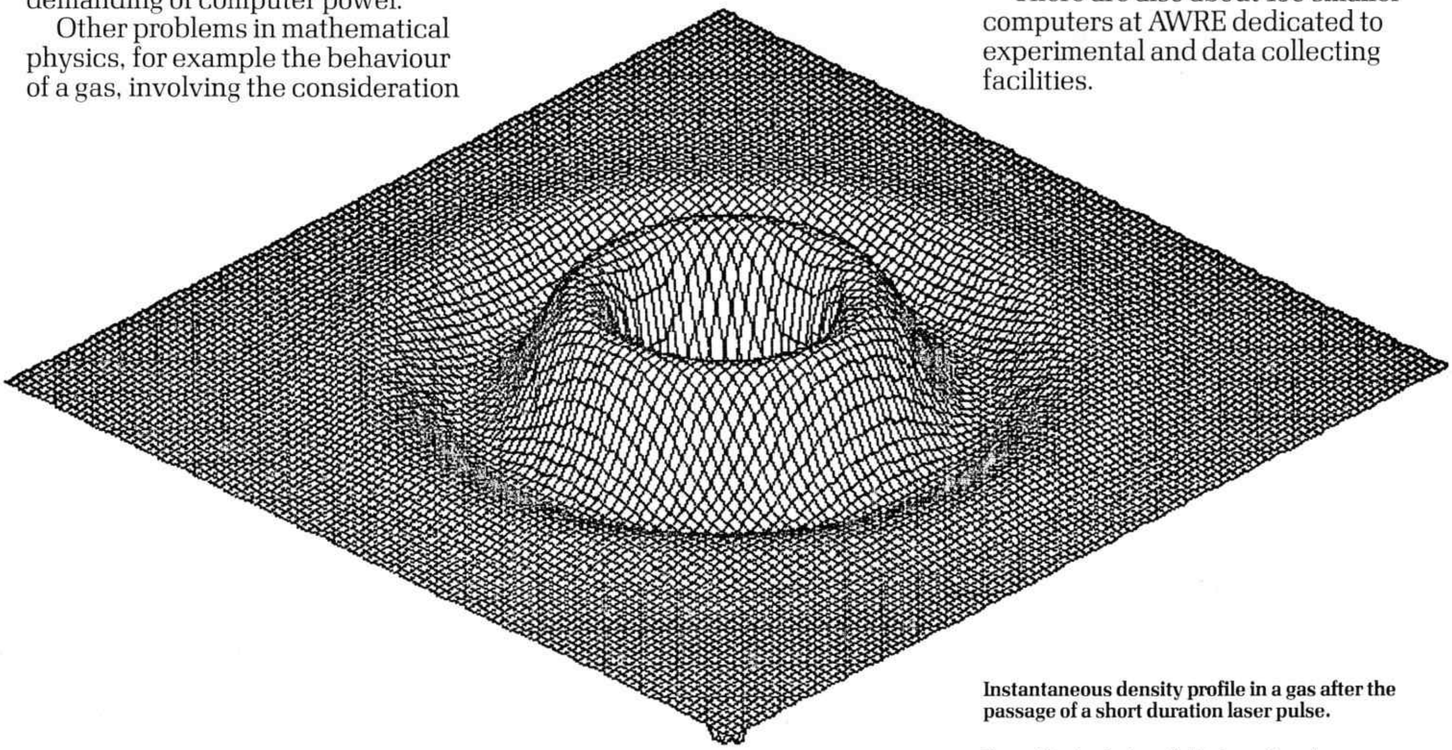
Other problems in mathematical physics, for example the behaviour of a gas, involving the consideration of the motions and interaction of hordes of elementary particles – molecules, atoms, electrons, or neutrons are often solved by even more sophisticated methods. Sometimes sets of equations are too large to be solved by any existing computer. It may then be more practical to adopt special methods, such as the Monte Carlo approach, which considers a sample of individual particles and processes each in turn in accordance with its appropriate physical law. The effect for each particle is 'a random walk' much as a bagatelle ball impacts on pin after pin, changing its velocity and direction at each collision. The chief application of the Monte Carlo method to AWRE problems is in the neutronics field, an example being the calculation of the penetration of neutrons through blocks of screening material in awkward geometry.

Computing

As cost, and political and environmental considerations, call for experimental work in nuclear weapons to be minimised, mathematical physics theory and numerical computation play a prominent part in the development of these weapons. At AWRE the demand for computer power exceeds the supply and the latest and most powerful computer available, the CRAY, is used.

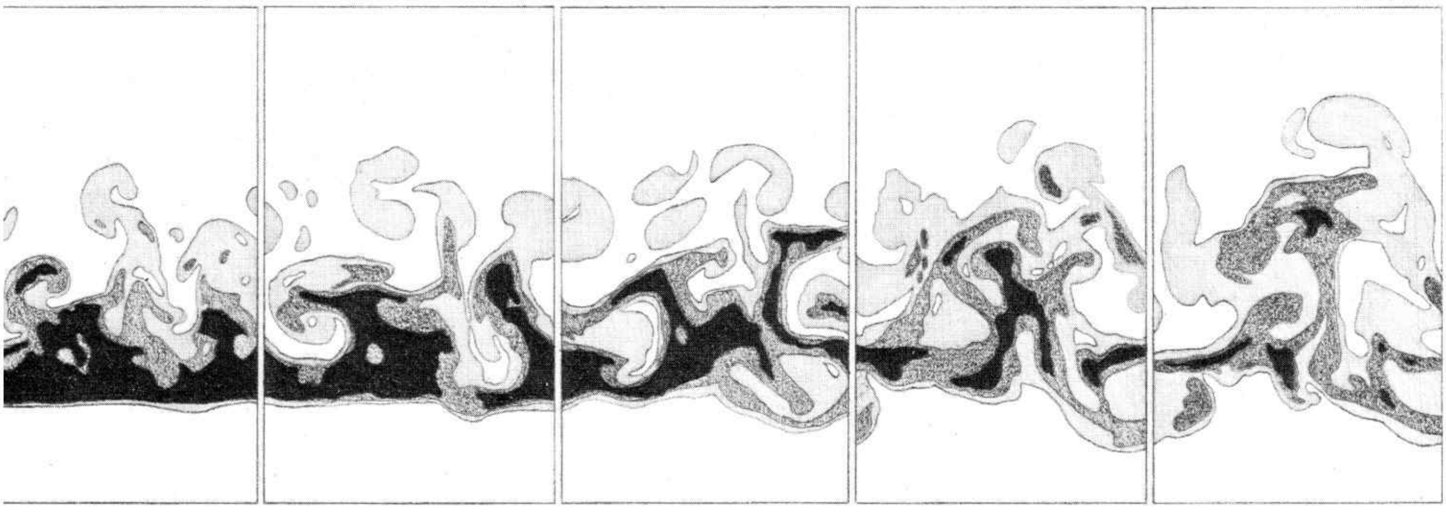
In assessing the results of mesh-type computations, such as those associated with hydrodynamics, a particularly useful role is played by computer graphics. Some 2,000 pictures a day are produced on an electrostatic printer, with a turnround time that keeps pace with line printer output. A remote terminal system has existed within the Establishment since 1967, and now comprises more than 100 terminals linked to the central computer.

There are also about 150 smaller computers at AWRE dedicated to experimental and data collecting facilities.



Instantaneous density profile in a gas after the passage of a short duration laser pulse.

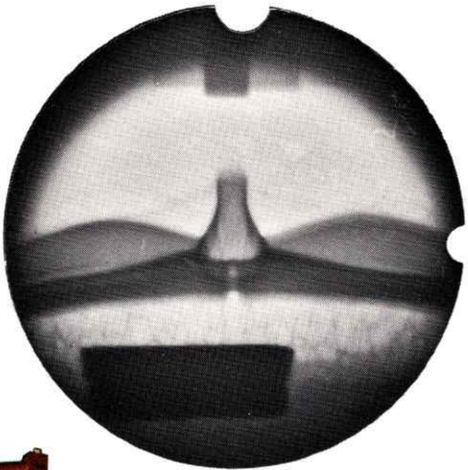
Turmoil calculation of thin layer break-up.



Warhead Hydrodynamics

Conventional explosives play an important part in the design of a nuclear weapon. The chemical energy released by the explosive reaction is used to change the fissile material from its safe resting configuration into a supercritical state. This produces divergent chains of nuclear reactions, which result in the rapid release of large amounts of fissile energy generating the immense yields associated with nuclear explosions. As Service requirements change, generally towards lighter and more compact devices, the warhead designer is faced with the problem of making the best use of the space available for conventional explosives; to store the chemical energy as compactly as possible; and then obtaining the greatest efficiency of assembly from it. The term 'assembly' is used in Warhead Hydrodynamics to describe the process of moving, reshaping and compressing the fissile mass. The development of facilities and techniques to satisfy the requirements of this process forms the main work of the Division.

During assembly, pressures of tens of millions of atmospheres are generated, which momentarily compresses materials to greater densities than they could normally experience by any other means. The propagation of detonation waves in high explosives is studied together with the properties of the detonation products, with emphasis on changes in behaviour induced in materials by the rapid compression. Electronic, optical and radiographic



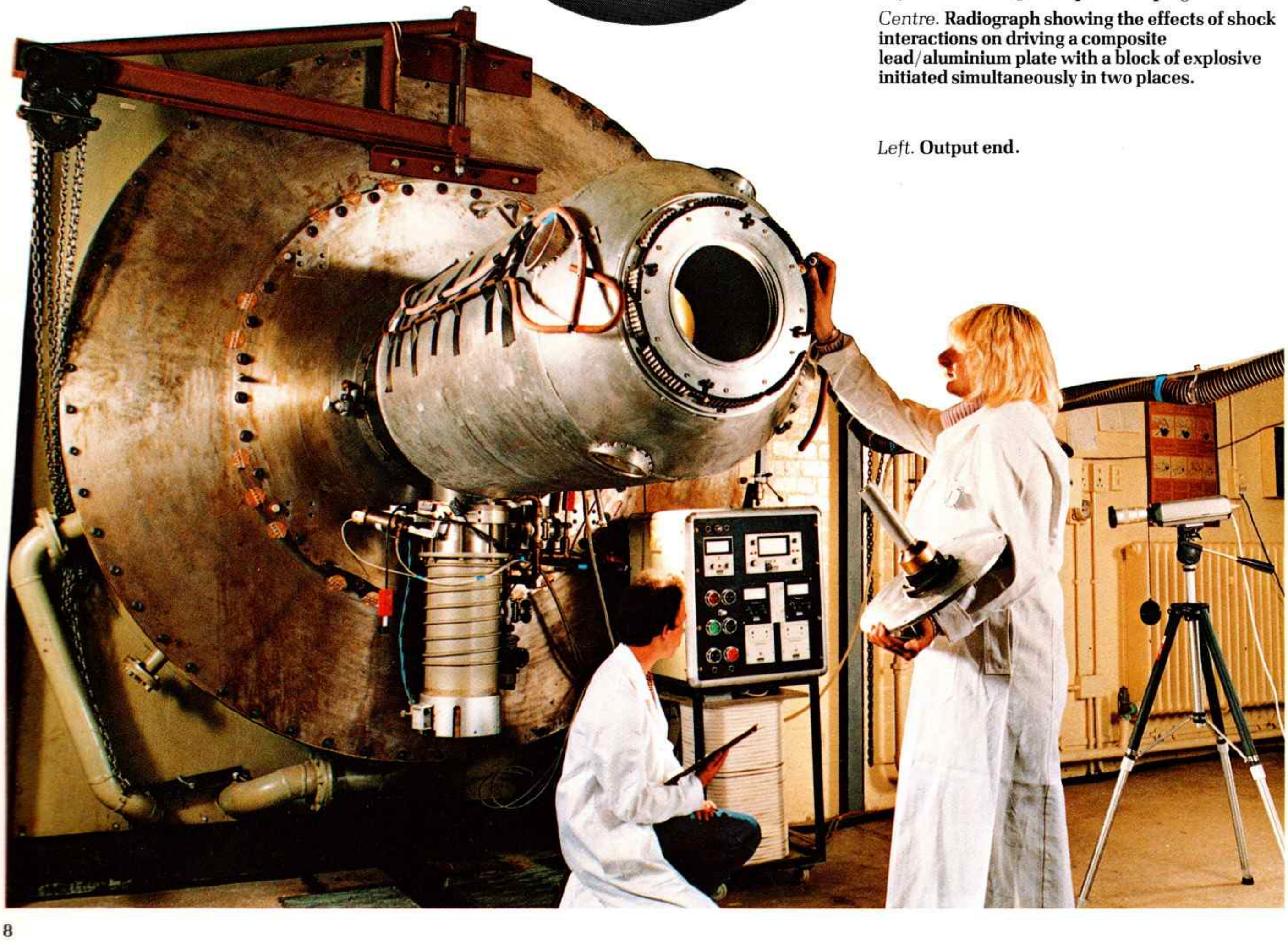
experimental techniques have been developed and are being continually improved. Recent advances in pulsed power generation have provided hydrodynamicists with a variety of flash X-ray machines which are able to take radiographs of events at exposure times of less than one ten millionth of a second, with a wide range of depth of penetration. This enables the condition in terms of density of transients within the metal and explosives present to be detailed as well as the state and form of internal interfaces.

MOGUL-D short pulse 8 MEV flash X-ray facility.

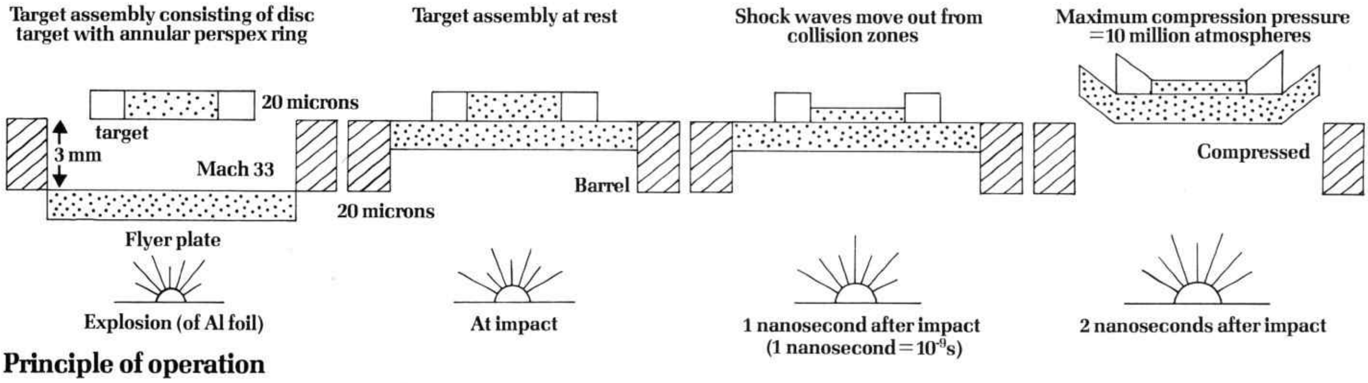
Top. **Power storage and pulse shaping section.**

Centre. **Radiograph showing the effects of shock interactions on driving a composite lead/aluminium plate with a block of explosive initiated simultaneously in two places.**

Left. **Output end.**



The electric gun and its use to strongly compress materials

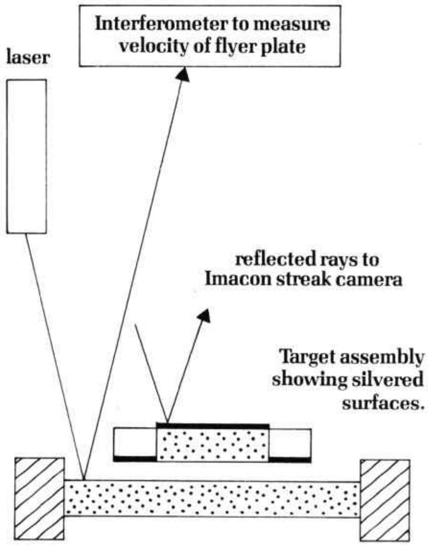


Principle of operation

The propellant used in the electric gun is aluminium foil. An intense current from a capacitor bank is switched into a narrow section of the foil causing it to change to high pressure aluminium vapour in less than one millionth of a second. The flyer plate is driven by both the expansion of the vaporisation and by magnetic repulsion.

Following an electrical explosion, the energy density of the aluminium vapour can be 25 times greater than that of typical high explosives.

Using this technique metals can be compressed momentarily to half their initial thickness.

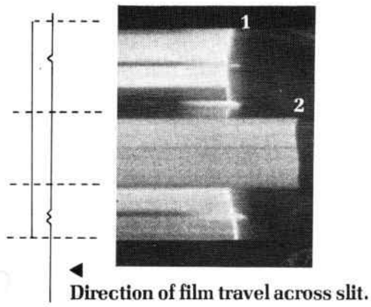


Measurement of flyer plate and shock wave velocities

The pressure from the explosion of the aluminium foil lasts for such a short time that novel instruments have had to be developed to enable the necessary transient measurements to be made.

Shock wave velocity

When the flyer plate strikes the target, the time taken for the shock to travel through it is determined by an Imacon streak camera. This photographically records the points at which reflectivity is lost from the back (1) and the front surfaces (2) of the target respectively, which enables the shock wave velocity to be deduced.



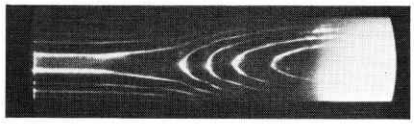
1 Arrival of shock wave at perspex (=back of target) disrupts reflectivity.

2 Arrival of shock wave at front of target disrupts target reflectivity.

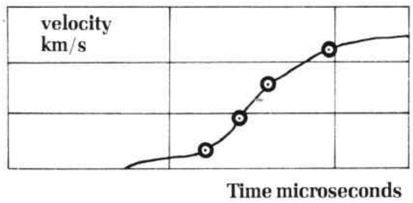
Flyer plate velocity

The upward velocity of the flyer plate is determined by the Fabry-Perot velocity interferometer in which the principle of the Doppler effect is used.

◀ Direction of travel across slit.



▲ Slit to allow light onto film.



Graphical interpretation of flyer plate velocity characteristics from streak camera record (top) of interference fringe disturbances.

The experimental work of the Division is supported by and interpreted using computational capabilities. Though these are primarily provided by the Mathematical Physics Department the Assembly Division plays an active role in adapting the hydrodynamic codes evolved to cope with particular configurations, and provides the data on properties of materials and explosives performance on which any hydrodynamic code needs to operate.

Although most of the work is related to nuclear weapons, support is given to other Defence Establishments concerned with the optimisation of non-nuclear armaments, where problems involving the advanced use of explosives or response to shock loading increasingly arise.

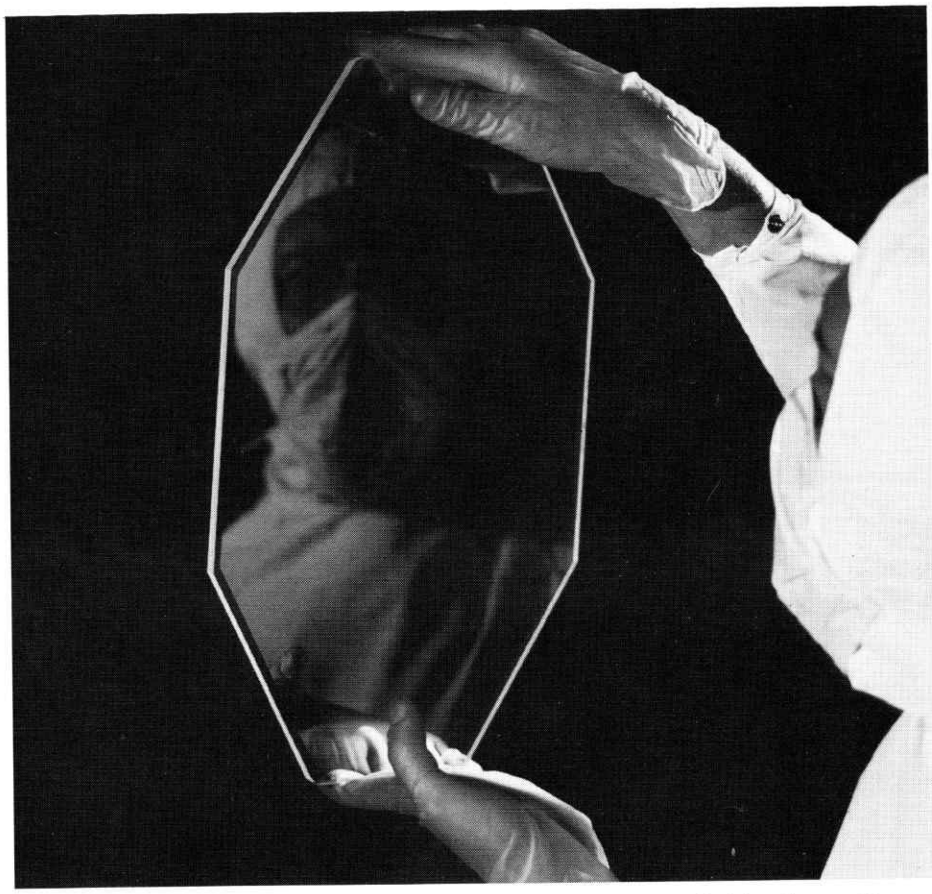
This is Grimm, the largest of four high current capacitor banks used for hydrodynamics research.

In a few millionths of a second it can deliver 25 million amps.

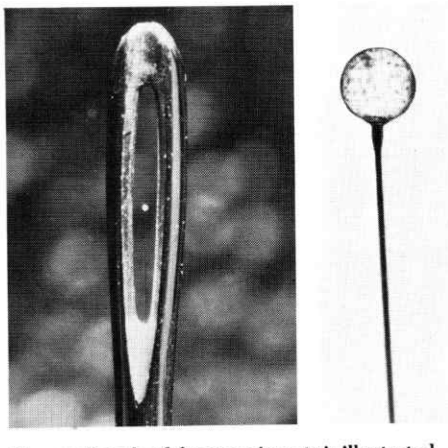
Radiation Physics

Laser applications to warhead physics studies

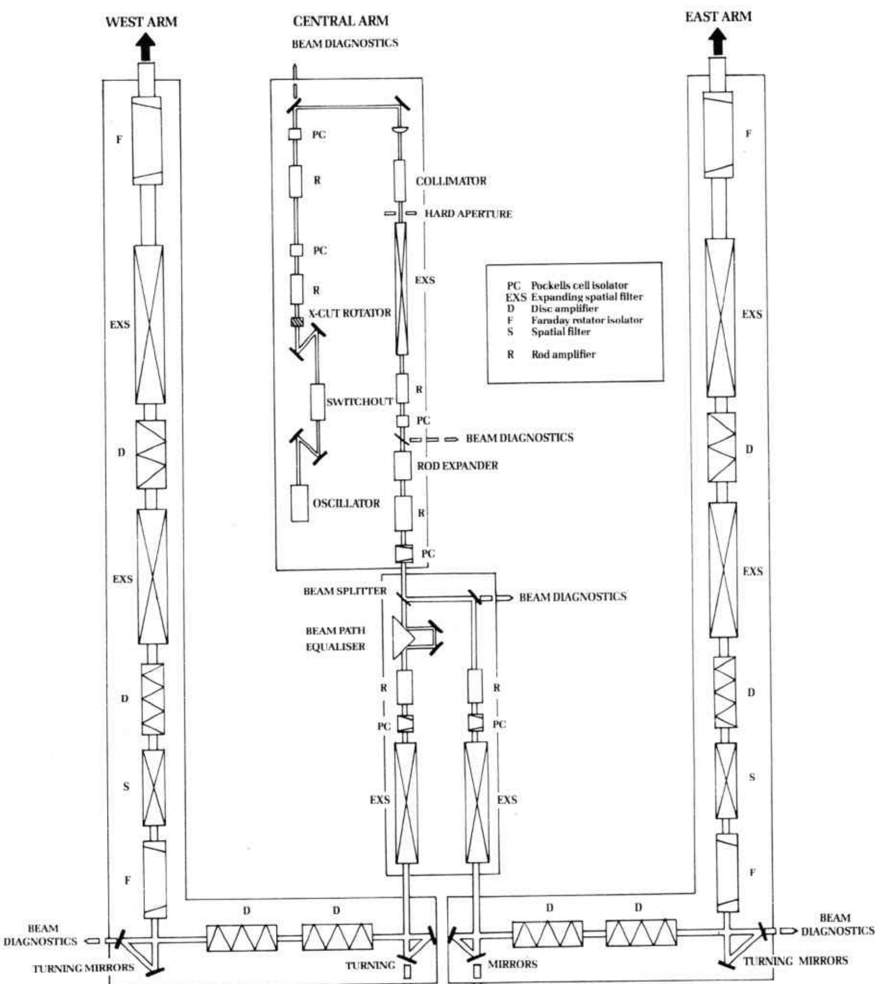
Nuclear weapons operate at extremely high temperatures and pressures, and successful design work depends on a thorough understanding of how materials behave in such conditions. Until recently it has been impossible to study these hot dense plasmas in the laboratory. Now, with the advent of high power lasers, such experiments can be done. AWRE has a very high power glass laser capable of focusing a short pulse of energy at over one million megawatts on a material sample less than one millimetre in diameter. The sample is heated instantaneously to a temperature of several million degrees, creating experimental conditions comparable with those in an exploding nuclear weapon. Experimental methods have been developed to measure the temperature, density and velocity of the material over a timescale of the order of one thousand-millionth of a second and to study the generation of thermonuclear fusion reactions.



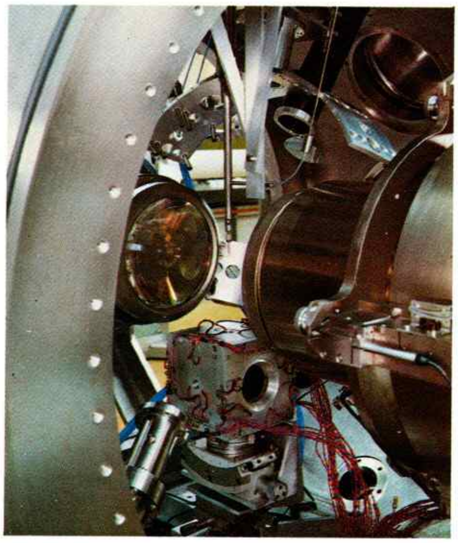
Multilayer dielectric polarising plate used in a Faraday rotator to protect against back-reflected light in the optical path of the laser. This one is being inspected in ultra-clean conditions to ensure freedom from blemishes which would be vulnerable to damage by the laser beam.



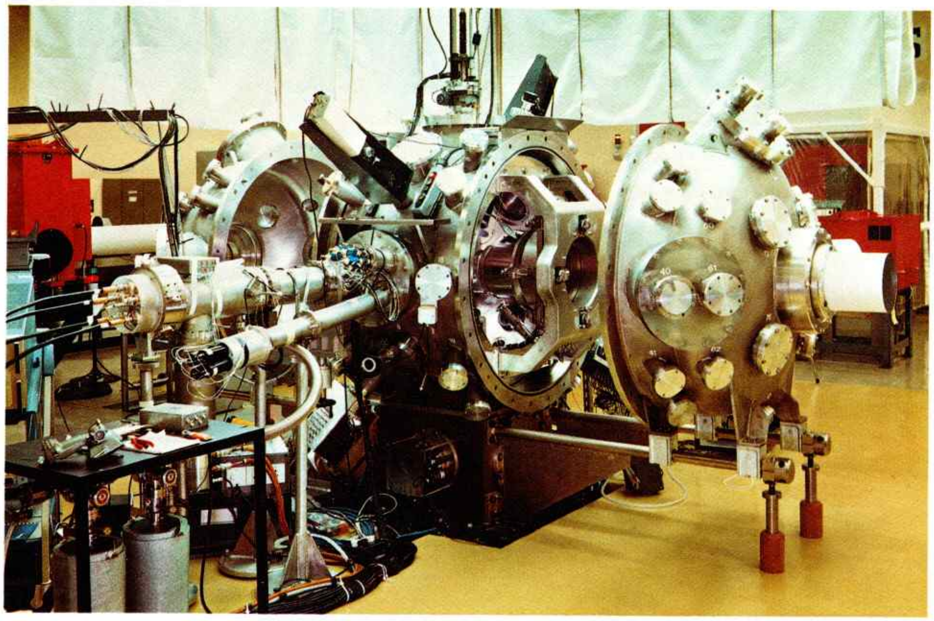
The small scale of the experiments is illustrated by this picture of one of them – a glass microballoon – shown here mounted in the eye of a sewing needle.



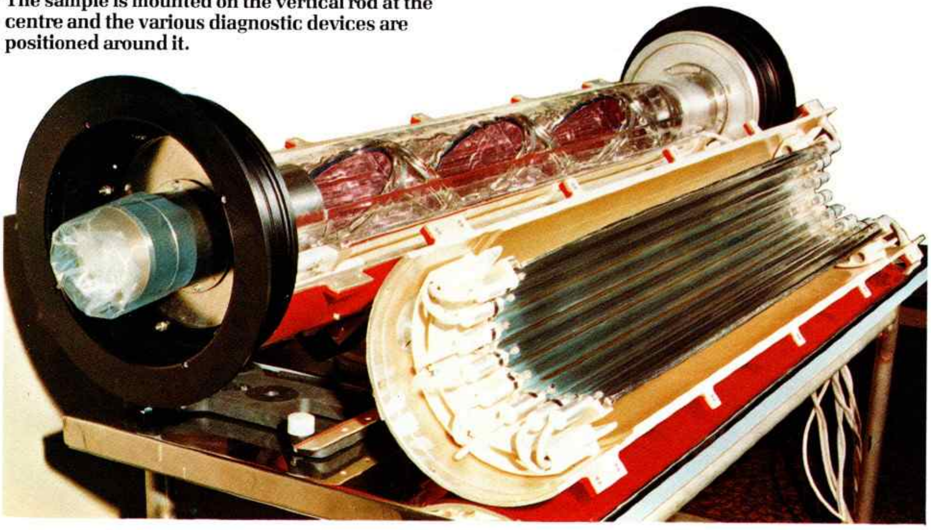
Schematic view of the high power glass laser showing the major components.



View inside the experimental chamber. The two laser beams are focused on to the experimental sample by large lenses, one of which can be seen. The sample is mounted on the vertical rod at the centre and the various diagnostic devices are positioned around it.

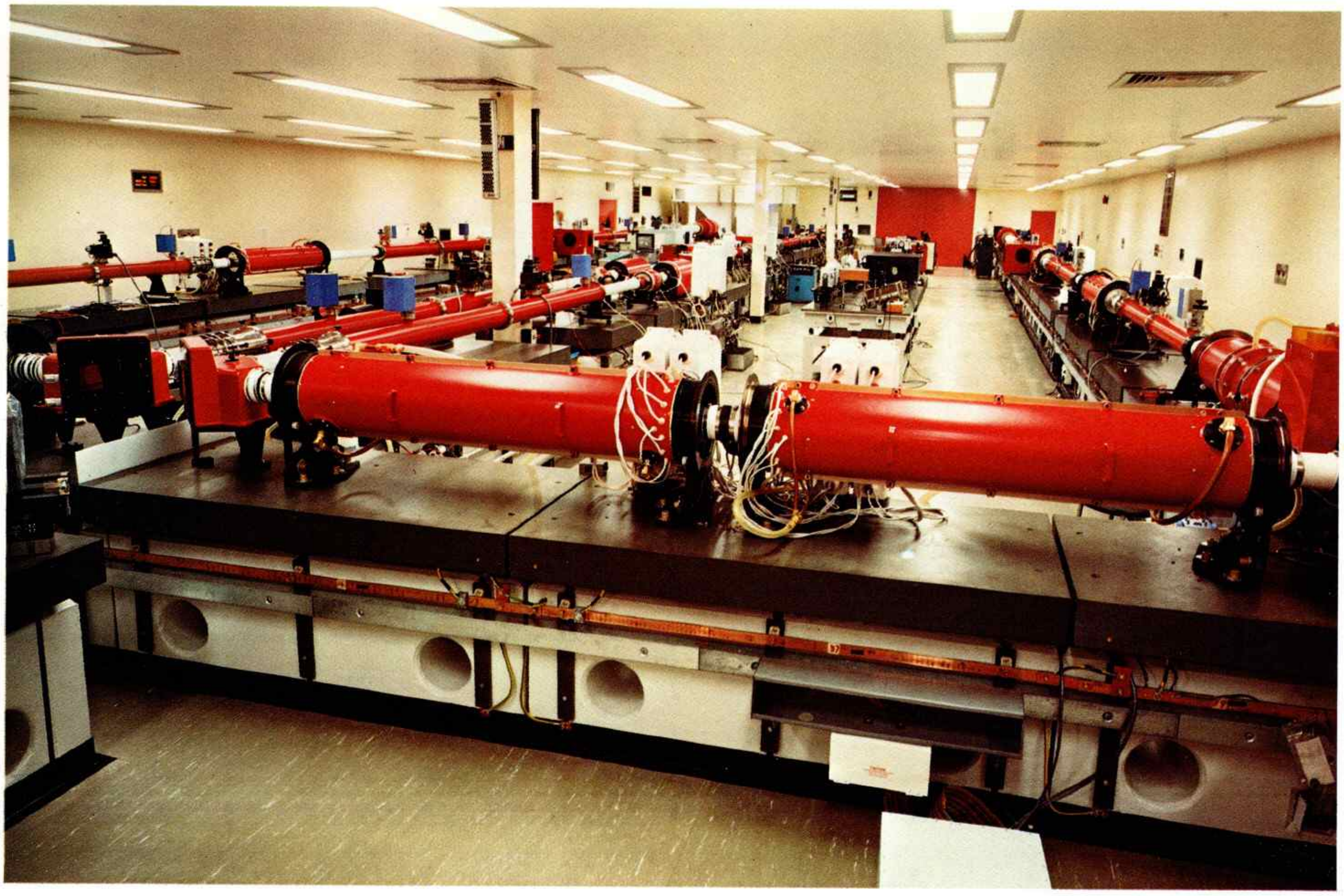


External view of the experimental chamber showing the diagnostic ports and the related equipment in position.



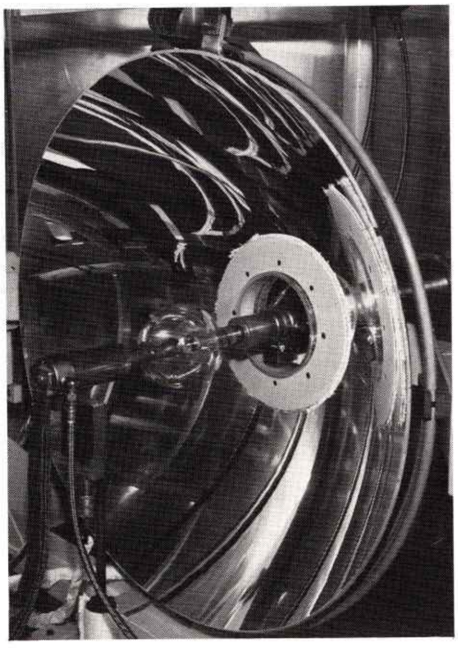
The laser comprises a pulse generator and a chain of amplifiers. This amplifier, shown open, consists of a set of Nd-glass discs surrounded by an array of flash tubes which provide the discs with stored energy. The bag is placed over the end of the tube to prevent the entry of airborne dust particles whilst the amplifier is removed from the system.

General view of the laser hall.

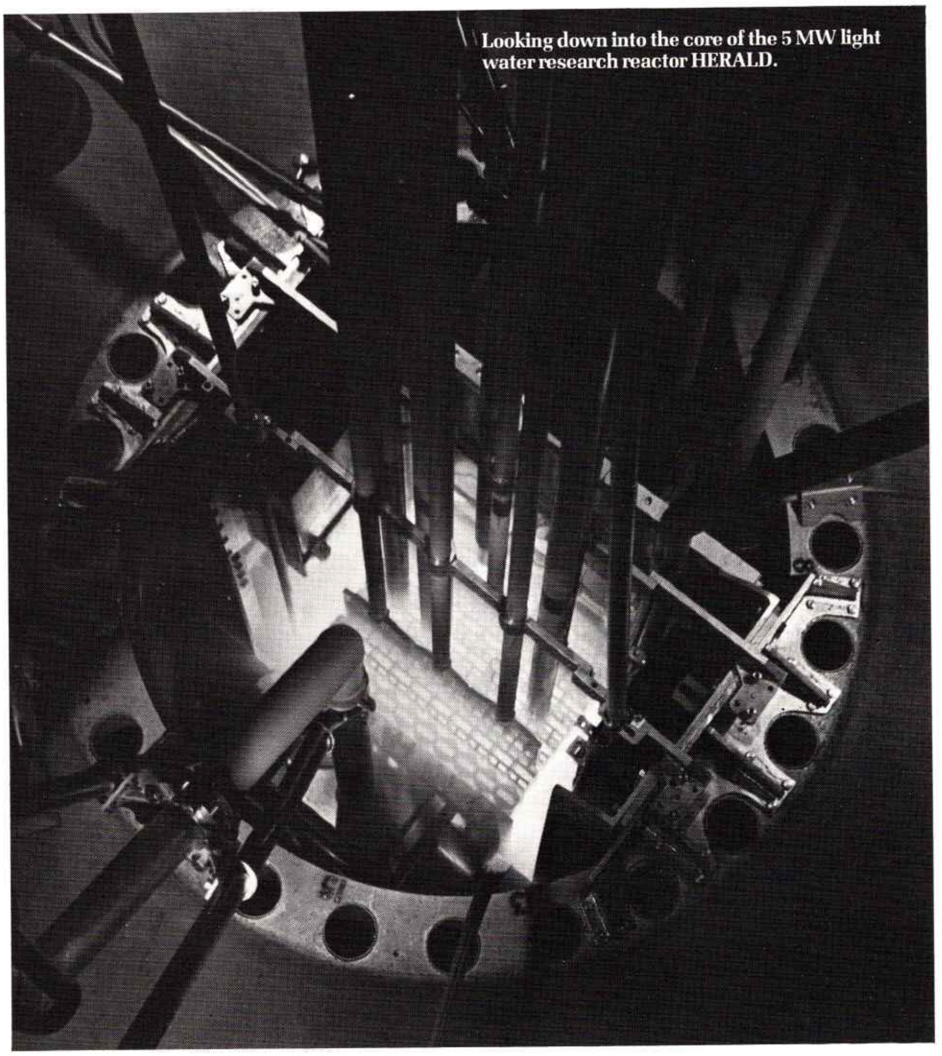


Nuclear reactor applications

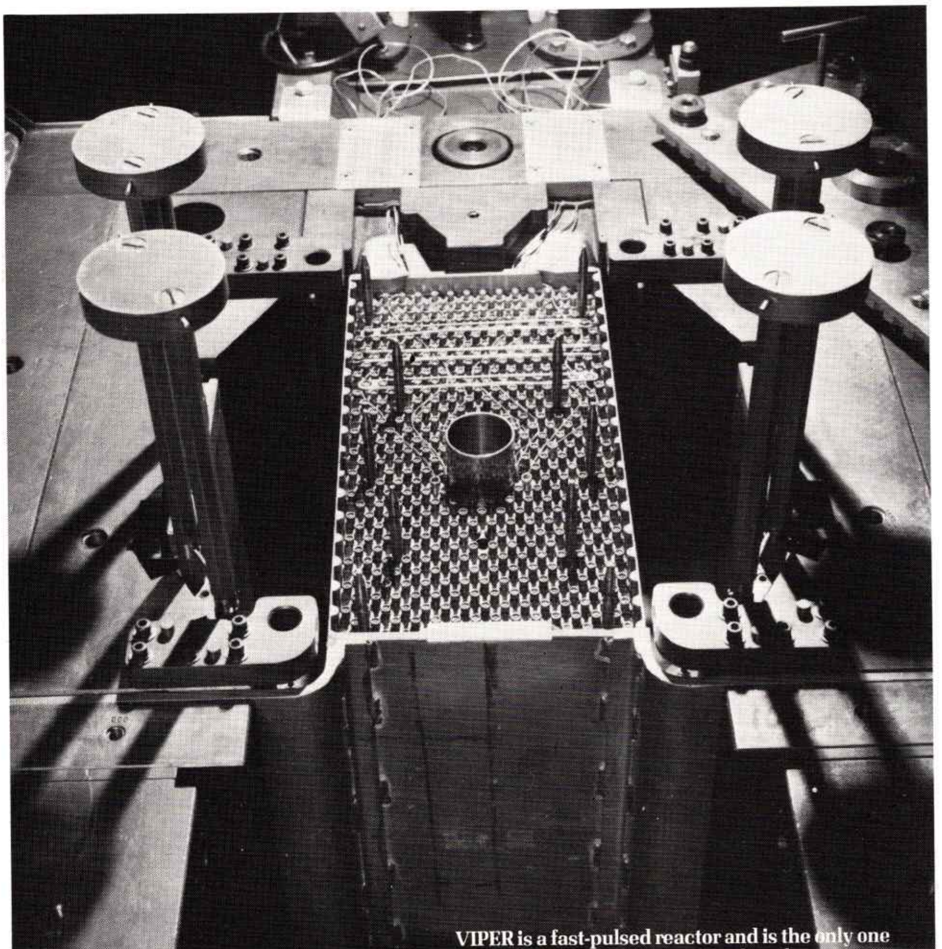
Nuclear reactors have a wide range of applications in studies of nuclear radiation effects and in the analysis of materials. AWRE operates a water-moderated reactor (HERALD) with a steady power of 5 MW and a pulsed fast reactor (VIPER) which has a peak power of 20,000 MW.



This is the lamp and mirror of a thermal radiation simulator. The curved mirror is used to focus the energy from the 30 kW arc lamp onto a sample two metres distant. The irradiation flux level is at several hundred cals/sq cm/sec.



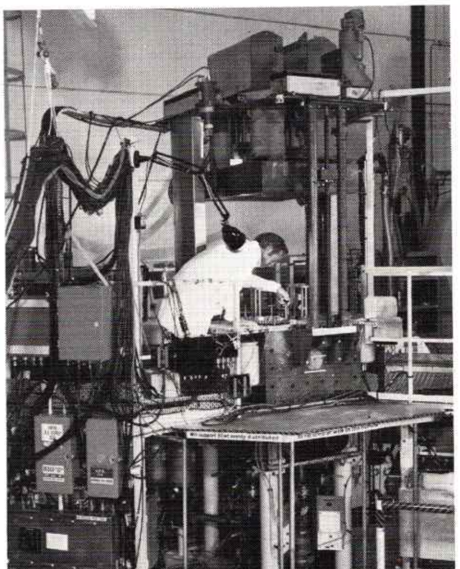
Looking down into the core of the 5 MW light water research reactor HERALD.



VIPER is a fast-pulsed reactor and is the only one of its kind in Europe. It can simulate the neutron flux from nuclear weapons to test their effects on materials and equipment.

HERALD is used for the study of defect distributions in materials by low temperature neutron scattering techniques, for the examination of components by neutron radiography and for chemical analysis of materials by neutron activation. Both VIPER and HERALD are used to study the effects of nuclear radiation on materials and on electronic equipment.

Setting up a VIPER experiment.



The Development of Nuclear Weapons

Having established the criteria for weapon design through the calculations of the Mathematical Physicists, the study of extreme shock behaviour by the Warhead Hydrodynamicists and the radiation properties of warhead materials and the effects of radiation upon them, the Weapon Engineers are able to design the warhead, with fuzing, arming and firing systems provided by Electronic Systems. Underground tests are arranged when necessary and the characteristics of the explosion are monitored through an instrumentation package which is one of the responsibilities of Weapon Diagnostics.

Preparation for a UK underground nuclear test at the Nevada test site. The assembly, including the diagnostic package, is being lowered into the borehole.

Photograph courtesy of Lawrence Livermore National Laboratory.

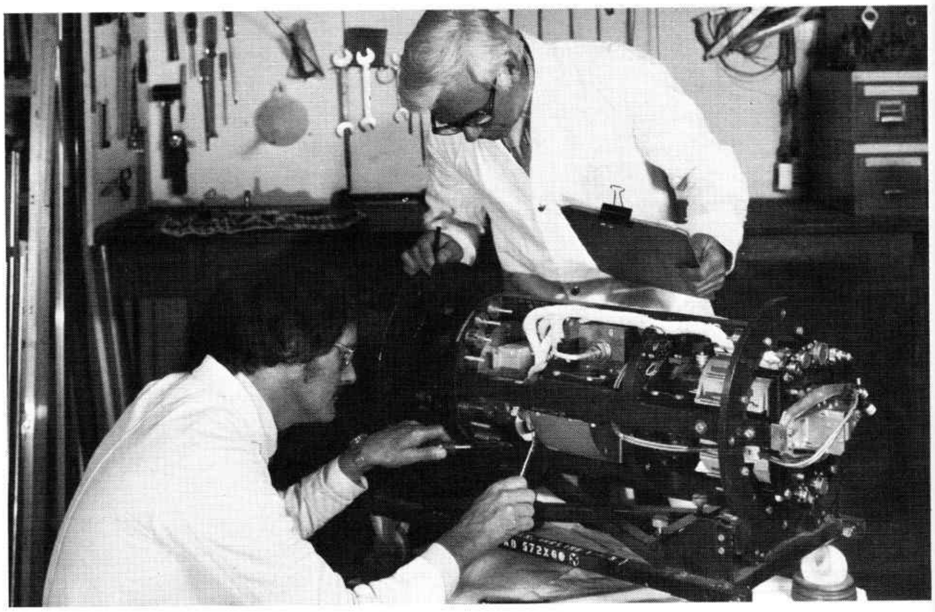
Weapon Engineering

The main task of the Weapon Engineering Division is to develop a unified warhead design, which may also include the bomb-case or re-entry vehicle, to the stage where the design is ready for manufacture. The division provides technical support to the production agencies and monitors the condition of the warheads throughout their service life. The aim is to ensure maximum reliability together with the achievement of rigorous standards of safety.

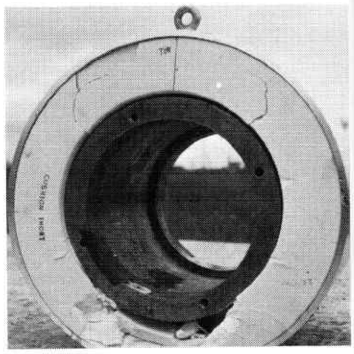
To undertake this work, Weapon Engineering is organised into several groups. Three of these are concerned with: formulating the engineering designs for the nuclear package; for the complete warhead; and for advanced engineering concepts. The work is carried out by a team of mechanical design engineers and there is close and direct support from electronics specialists, explosives experts, materials scientists etc. Detailed drawings and performance and process specifications are provided by the appropriate design team who have an intimate knowledge of the design standards for military equipment and the special engineering characteristics of the unusual materials used in the nuclear components.

The design teams are backed by a large Drawing Office organisation which has at its disposal an interactive computer graphics system and computer aided draughting (CAD) facilities, which are continually being updated and extended as their potential is developed. The Drawing Office maintains a comprehensive Design Standards Library.

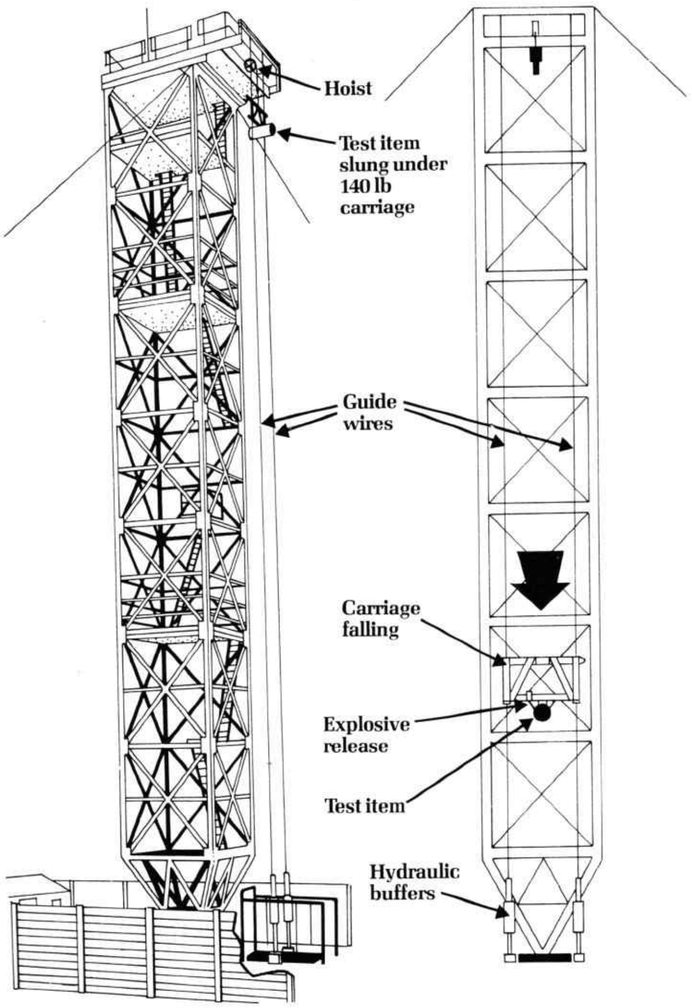
Within the division one group of



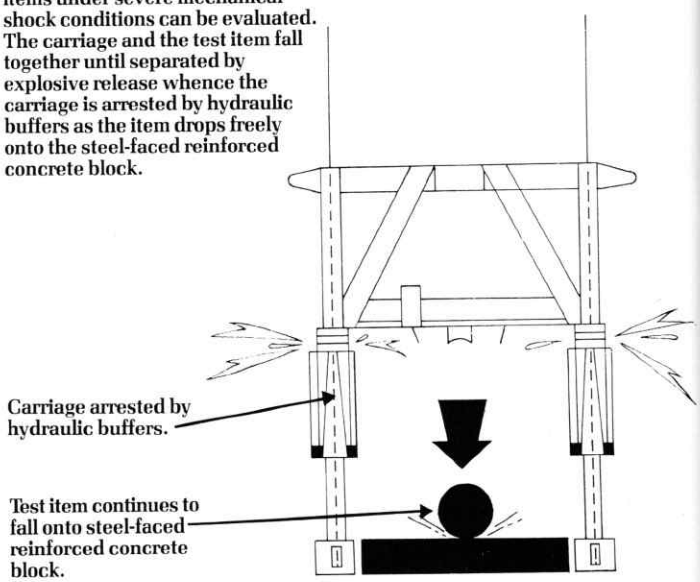
Tests are conducted to ensure that the warhead remains in a serviceable condition after being subjected to the Stockpile to Target environment.

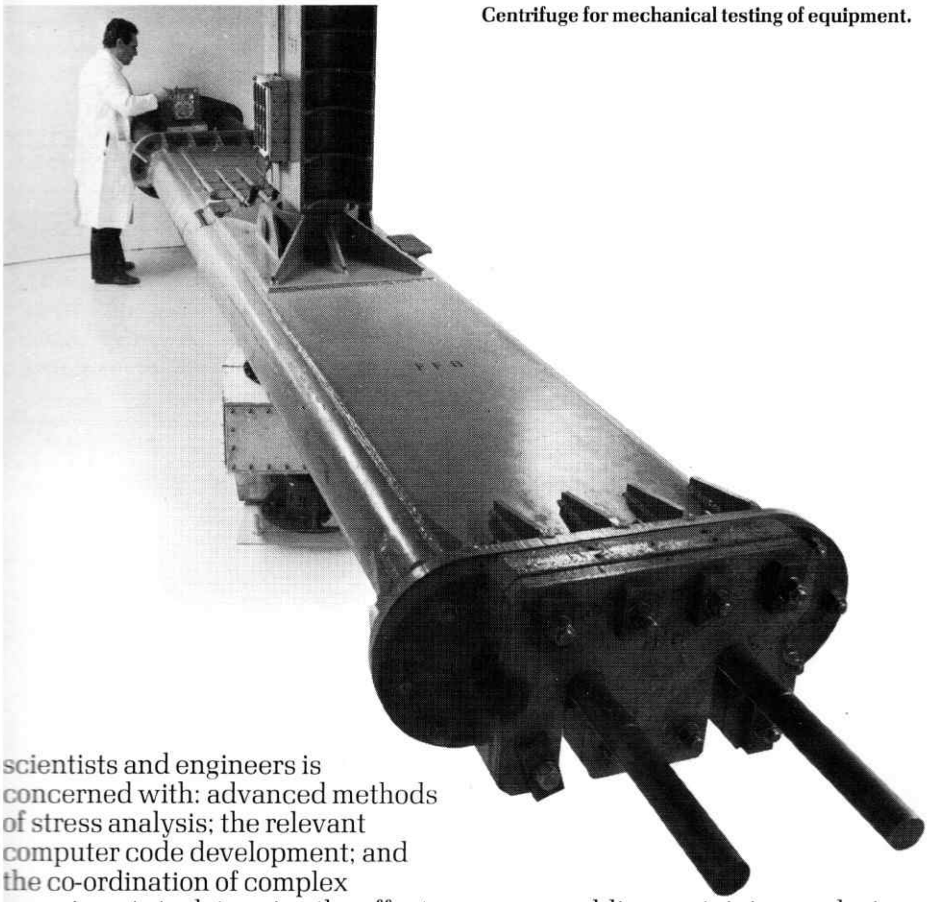


Drop test experiment to evaluate packing configuration.



One of the environmental test facilities is the 100-foot drop tower, by which means the behaviour of items under severe mechanical shock conditions can be evaluated. The carriage and the test item fall together until separated by explosive release whence the carriage is arrested by hydraulic buffers as the item drops freely onto the steel-faced reinforced concrete block.





Centrifuge for mechanical testing of equipment.

To confirm the safety of a weapon it is subjected to a series of trials representing a variety of accident conditions.

scientists and engineers is concerned with: advanced methods of stress analysis; the relevant computer code development; and the co-ordination of complex experiments to determine the effects of unusual loads, particularly fast transients, on compound structures (Underground Effects Tests).

A major undertaking in any project is the experimental work required to establish the viability of a design. This is particularly so in the case of a nuclear warhead which must safely survive the severe environmental conditions it will encounter throughout the manufacture to target life, and then function reliably when required. The Weapon Engineering Division includes a large group with the equipment to simulate all these conditions. The mechanical environmental test facilities at AWRE are the foremost in the United Kingdom, and are capable of applying vibration, shock, steady acceleration, pressure and thermal effects on inert test items, as well as on assemblies containing explosives or other hazardous materials. Comprehensive analysis and the provision of specialist advice on environmental testing specifications and methods are further services offered by this group, which also has access to other facilities both on site and elsewhere including overseas.

In the development of modern nuclear weapons, the definition and the provision of components for the experimental work, presents a considerable logistic problem. This work necessarily takes place over an extensive period, during which time the designs are being refined. The designers and trials engineers are supported by a Procurement and Planning group which ensures that the correct hardware is available from the manufacturing agencies at the right time in the trials programme. Dedicated computer facilities are used to assist in this complex task.

Nuclear weapons are approved as safe and suitable for Service use through a formal system of safety committees and assessment panels. This requires the design and the trials evidence to be presented in the form of submissions for approval. Similarly the handling and operating manuals for the Service user are issued in an authorised form. These tasks are handled by the Technical Documentation Group who are intimately involved in the development from its inception. Much increased efficiency has resulted from the use of word processors in this documentation.

The Post Design Services Group monitor the stockpile of weapons and confirm their continued safety and serviceability. This is achieved by accelerated life trials in the laboratory and the inspection, testing and analysis of weapons in service.

Weapon Diagnostics

In its role of atomic weapons research the establishment develops warheads to meet the current Service requirements to maintain Britain's policy for nuclear deterrence. For this to be effective it is necessary to test new designs, to evaluate their resistance to counter-measures and to study the effects of nuclear explosions on items of interest. Since the ban on atmospheric nuclear tests, the only place where warheads can be detonated is underground.

Simulators

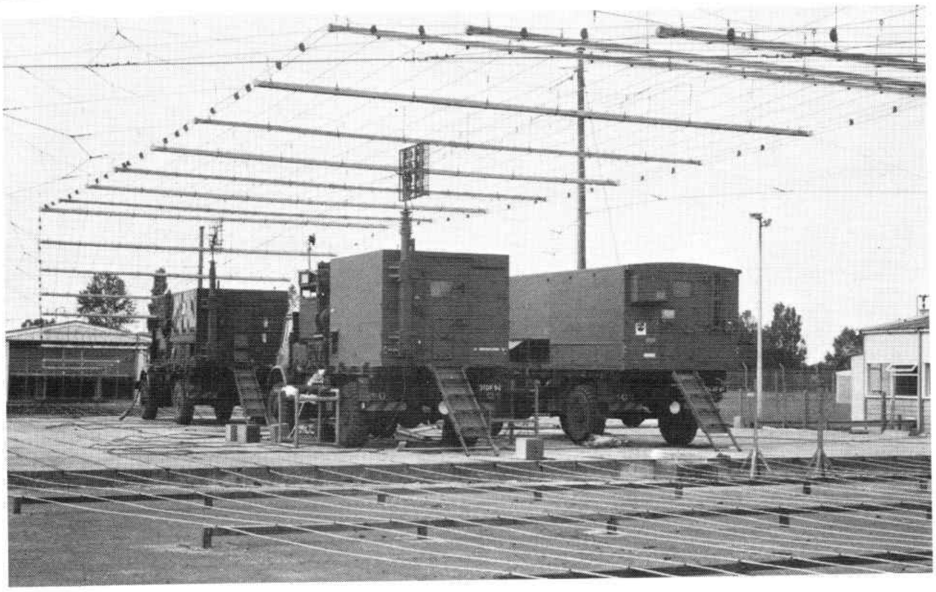
Effects tests are necessarily costly, therefore to minimise expenditure much effort at AWRE is devoted to the laboratory simulation of the behaviour of the different characteristics of a nuclear explosion, and the various effects obtained from them.

Described elsewhere in this brochure are the HELEN pulsed neodymium laser and the HERALD and VIPER reactors; the compression simulation by explosives in Warhead Hydrodynamics, and the blast effects studied at Foulness.
The Weapon Diagnostics Division operates a host of simulators which are capable of producing powerful X-rays, electron and laser beams and electromagnetic pulses, e.g. the HPL10, AVCO CO_2 laser produces a 25 kW continuous thermally damaging beam. An important member of the range is EROS, which is a high intensity pulsed radiation facility designed at AWRE.

The power supply unit for PETS

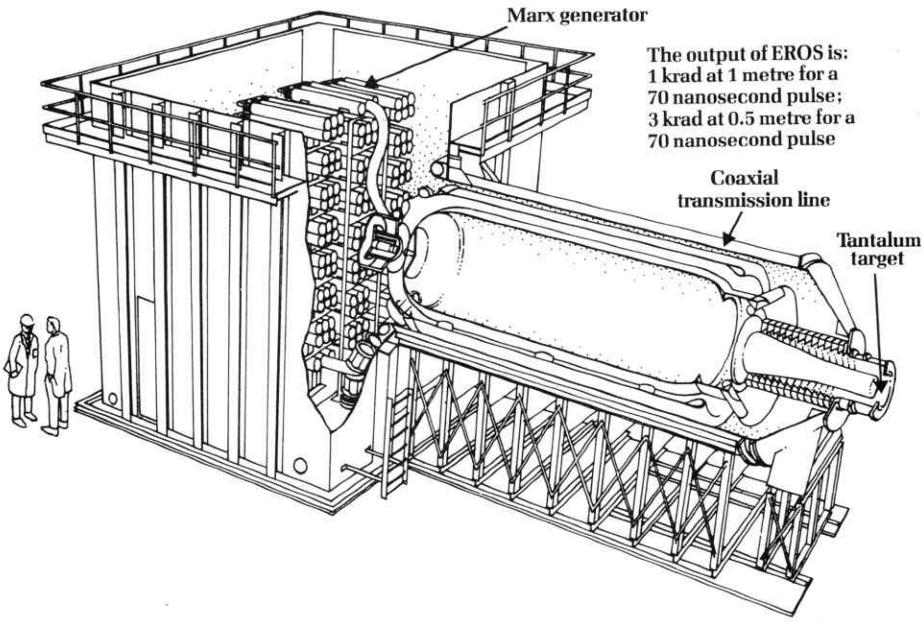
PETS

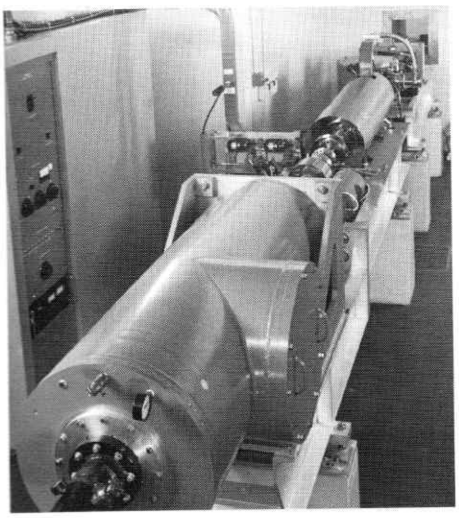
This simulator originally installed and developed by AWRE has been used to subject many items of military equipment, e.g. tanks and antennae, to electromagnetic pulse effects. New simulators are being developed to study the effects of EMP on communications.



EROS

The purpose of this machine is to simulate the fast pulse of γ radiation from a nuclear explosion, making it suitable for studying the transient γ effect on electronics.
Photons are produced from a tantalum target, which is irradiated with a burst of fast electrons. These electrons are produced via a Marx generator (used in several of the Division's X-ray and electron beam simulators) which achieves a high voltage surge by fast switching a set of condensers from parallel to series configuration. The sequence which leads to the production of the pulse is started by shorting out the line to the Marx generator.





A 10 MW electron beam LINAC used for simulation. Current applications include radiation tolerance assessment of microprocessors, missiles and aircraft power supply units. The dose rate is 10^6 to 10^{10} rad/sec with a pulse length from 5 nanoseconds to 5 microseconds.

Seismology

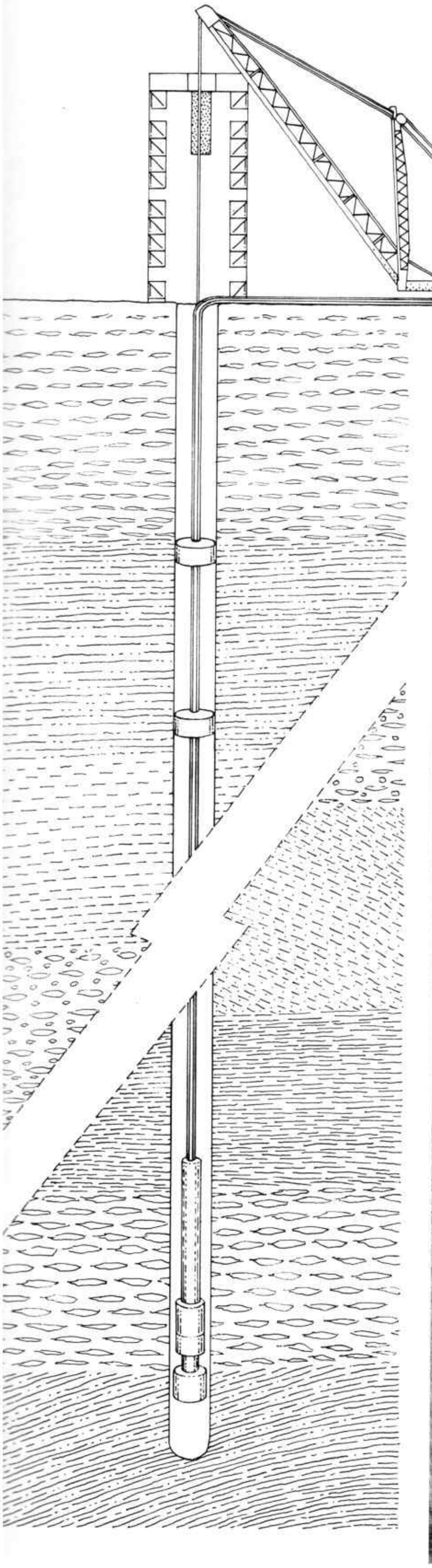
Foreign underground tests are monitored using seismological equipment and techniques developed at AWRE. Much research has centred around establishing methods of differentiating between the tremors from earthquakes and those generated by underground tests.

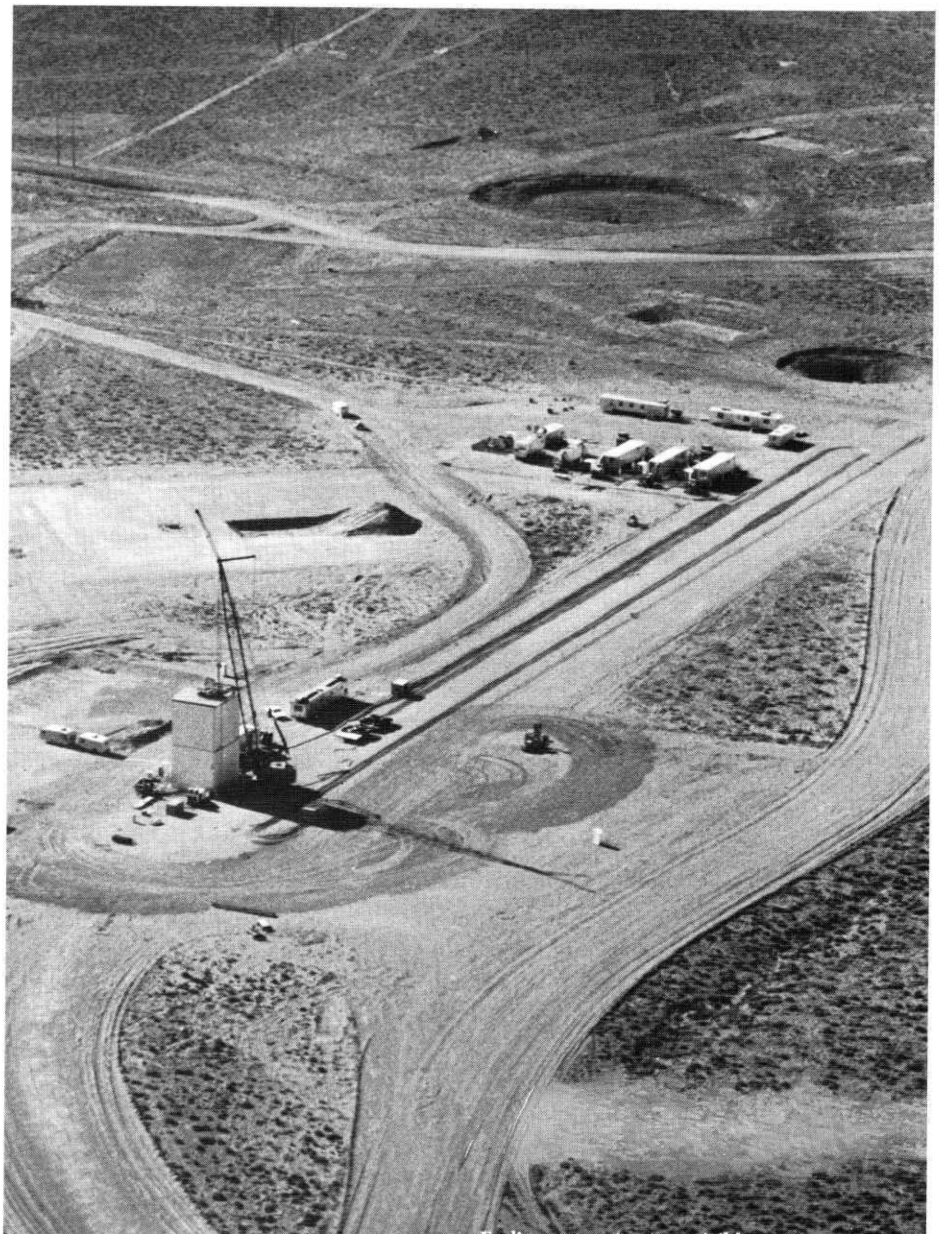
Underground Tests

However much simulation is carried out, confirmatory tests of warhead design and performance have to be carried out underground. These tests take place in the Nevada Desert under the terms of the 1958 Agreement for co-operation on the uses for Atomic Energy for Mutual Defence Purposes between the governments of Britain and the United States. When a nuclear warhead is exploded underground, it is important to obtain as much information as possible about its characteristics. Directly above the warhead itself is a diagnostic package, which may be more than 90 feet in length whose array of instrumentation is the responsibility of the Division. Although these instruments survive only the first few moments of the explosion, the records of their measurements are transmitted to the surface and then to the recording trailers for the telemetry caravans before the package is vaporised in the hostile environment.

A hole up to eight feet in diameter is drilled vertically into the desert, to a safe depth depending on the anticipated yield of the warhead under test. The device is then lowered from the tower together with the diagnostic package and cables are led to the recording trailers positioned several hundred yards from the hole to the telemetry caravans many miles distant. Because of the shock movements of the earth's surface when the warhead is detonated, the trailers are mounted on blocks, and during this time are not staffed. Following the test the recorded data are analysed to assess the efficiency and performance of the warhead.

All activity remains safely sealed beneath the surface, but an interesting phenomenon associated with nearly all tests is the subsequent ground collapse which forms a large crater. This is because the explosion vaporises the sub-terrain in its immediate vicinity. On resolidification it occupies a smaller volume than before, and the void so produced starts the chain of successive subsidence which may take hours to reach the surface.





Earlier craters *(top)* are visible as preparations are made for the next test in the Nevada Desert.

Photograph courtesy of Lawrence Livermore National Laboratory.

Electronic Systems

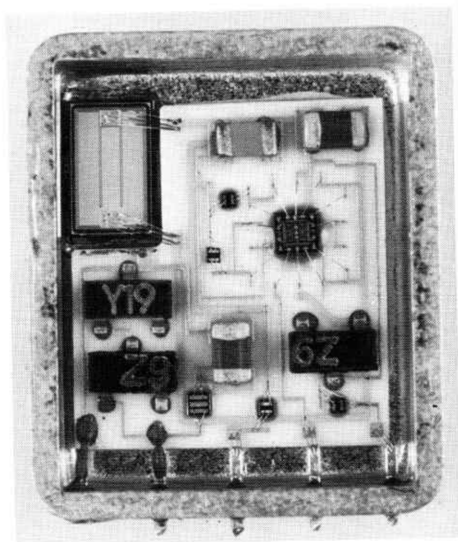
A wide range of research and development on electronics is carried out in the Electronic Systems Division. This work includes the development of arming, fuzing and firing systems associated with nuclear weapons, where very high standards of design and manufacture are required to ensure reliability and safety under severe environmental conditions, including nuclear radiation, after long periods of dormancy. The designs also have to meet complex security and safeing requirements for protecting the weapon systems. Special purpose components for functioning the warhead systems have to be designed, manufactured and tested to ensure their performance and life under extreme conditions. High grade vacuum physics laboratories support the manufacture of special weapon electronic components and sub-systems.

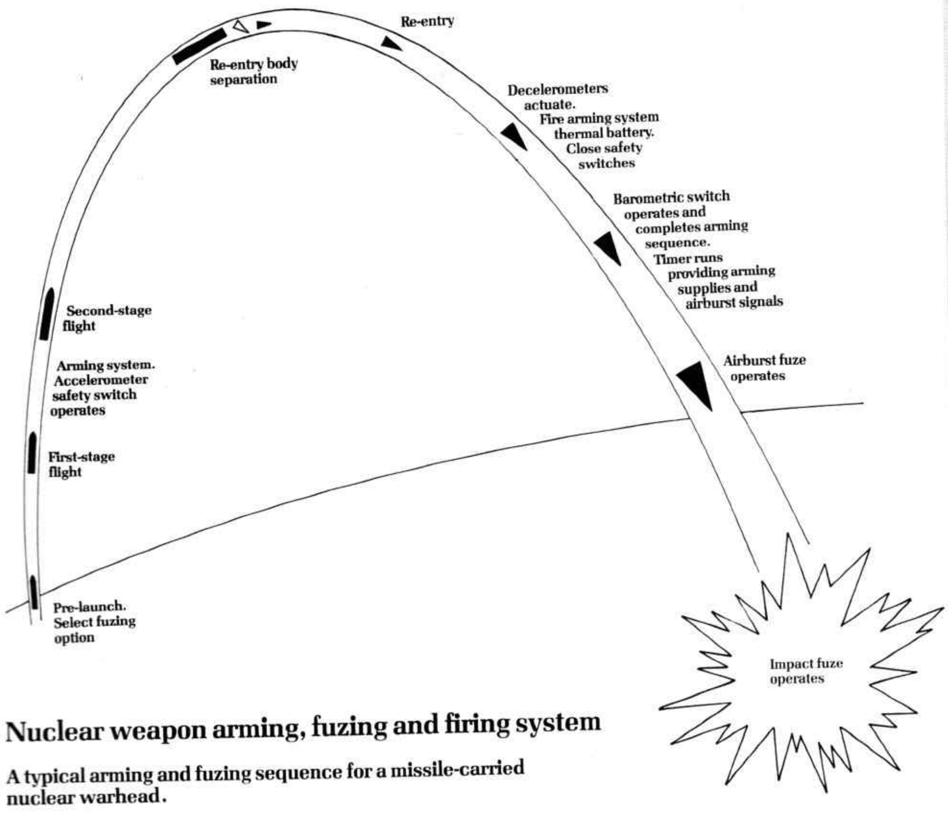
Extensive use of large scale integrated circuits and microprocessors is made throughout the Division, which has the capability of designing special purpose integrated circuits when required. The development of new and complex electronic techniques is supported by facilities such as a CALMA interactive computer graphic facility and photoplotter, a thick film manufacturing facility, automated test equipment and well equipped workshops. Use of these facilities enables exceptionally high degrees of miniaturisation to be achieved when required.

The extensive use of minicomputers and microprocessors requires substantial software development. In addition, considerable use is made of mathematical modelling in relation to system design and performance, including communications systems, the necessary programs stretching even the main site computer to the limit of its capacity.

CALMA interactive computer graphic facility.

Stabilized high voltage generator. Actual size 15 mm x 13 mm.





Nuclear weapon arming, fuzing and firing system

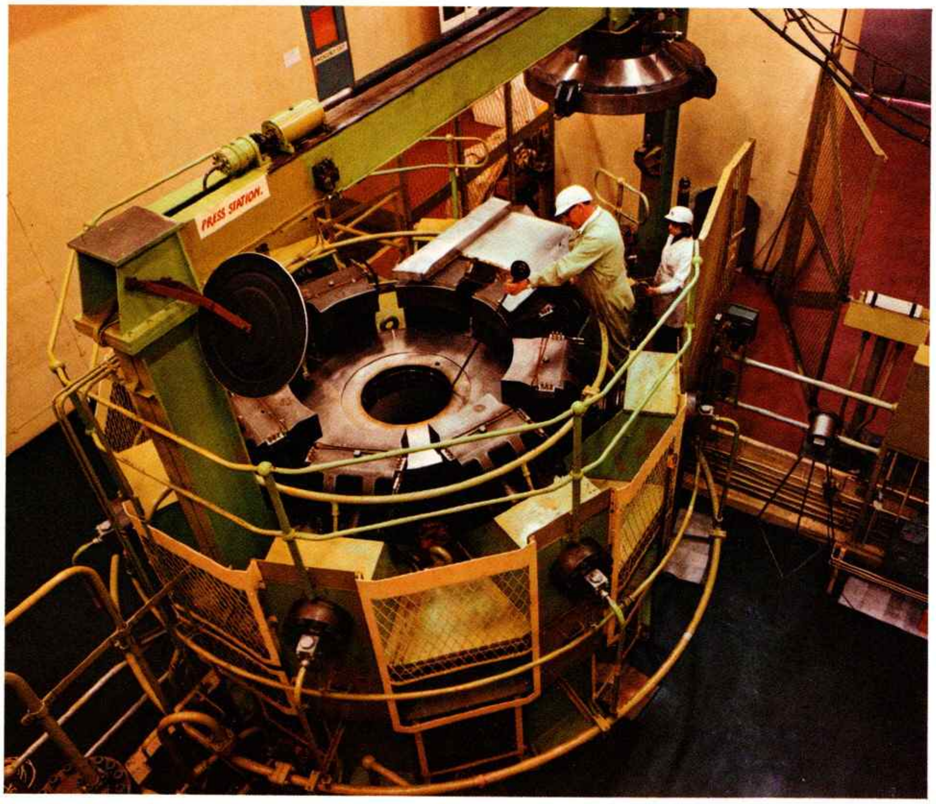
A typical arming and fuzing sequence for a missile-carried nuclear warhead.

Integrated circuit development for warhead arming and fuzing.

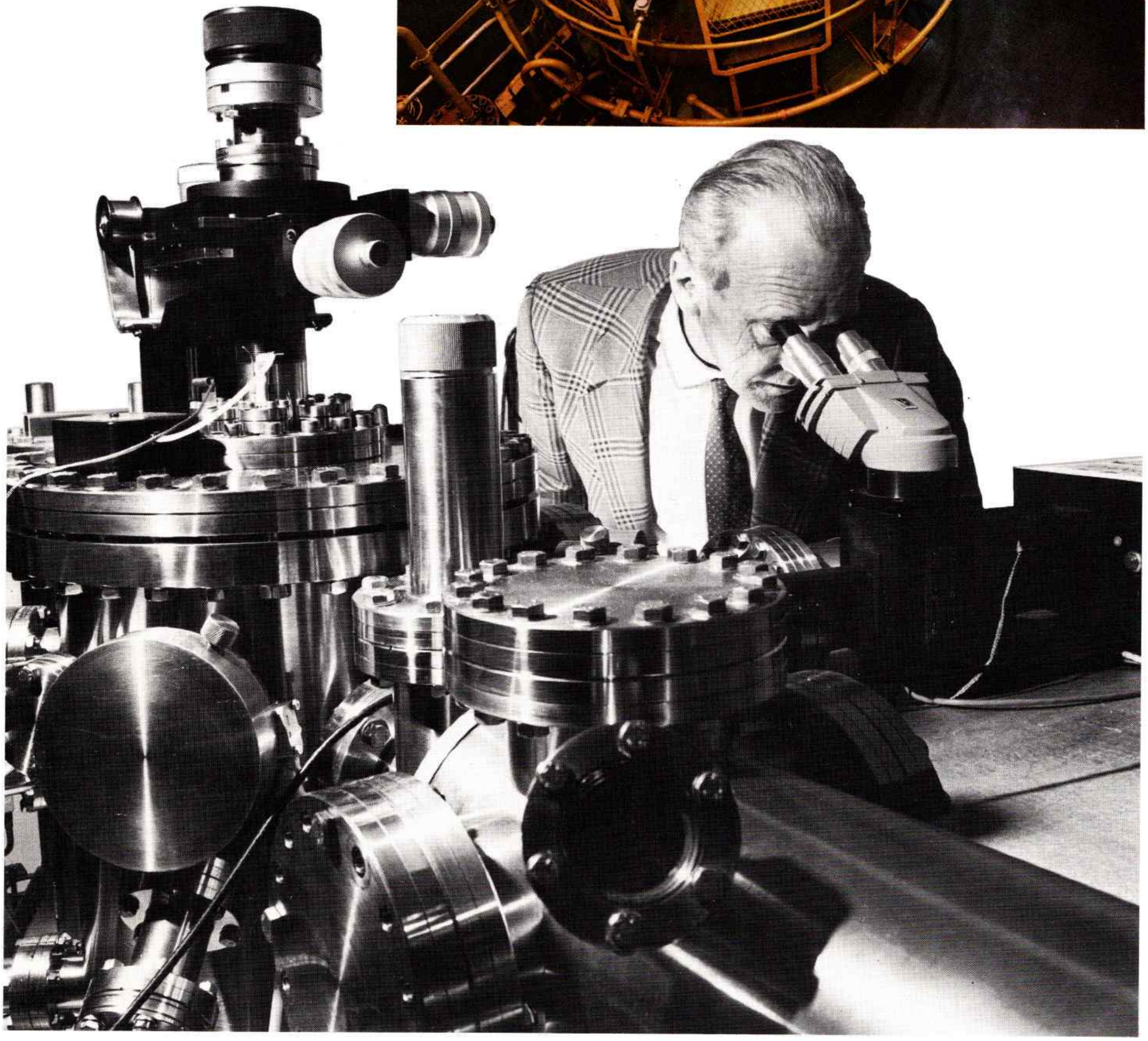
The weapon programme at AWRE requires the use of complex firing circuits capable of operating in severe environments. Custom integrated circuits are developed in the following way. Each circuit is designed for a specific purpose and consists of a number of different logic cells interconnected to produce the required characteristic. The design is drawn and input to an interactive graphic display system, which is programmed to lay-out the design to suit the chip and arrange the logic cells using optimisation techniques to obtain minimum interconnection lengths. The computer is also able to simulate and predict the performance of the circuit ensuring integrity of design.

Materials for Nuclear Weapons

The Materials Department at AWRE is formed from the disciplines of Chemistry and Explosives; Chemical Technology and Metallurgy.



Checking the oil temperature in a press used in the Chemistry and Explosives Division. The press enables high density explosive charges to be compacted.

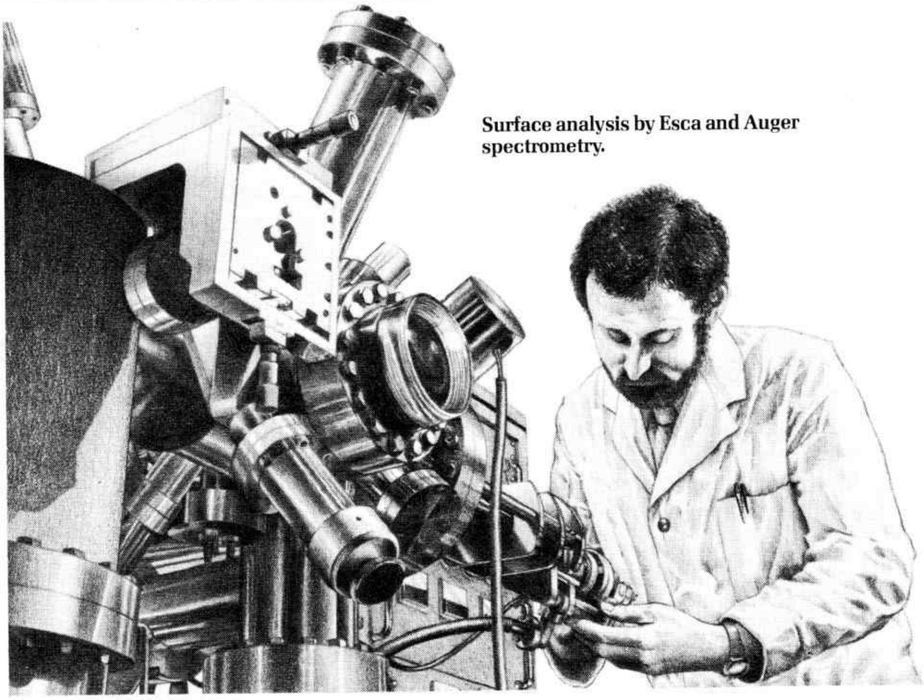


**This laser ionisation microanalyser enables parts per million concentrations of elements within metals to be determined.
Operated as part of the Metallurgy Division's array of specialised equipment, it also provides a service in its field to the establishment as a whole.**

Chemistry and Explosives

The Chemistry and Explosives Division provides essential support in the development, manufacture and surveillance of nuclear warheads and maintains a thriving research programme as a basis for future technology. Where its facilities and expertise are unique, these are also used for some defence and civil projects in the national interest.

The deployment of professional chemists is particularly important in the areas of radiochemistry, chemistry of fissile and other radioactive materials, chemical compatibility, chemical and isotope analysis and materials characterisation. Explosives technology is vital to warhead development and calls not only on chemists, but also physicists, mathematicians and engineers through inter-disciplinary teams.



Surface analysis by Esca and Auger spectrometry.

Chemistry

The radiochemical analysis of fission and activation products by chemical separation and radiation counting techniques provides key diagnostic information on the performance of nuclear devices. Support in this area is also provided by isotopic mass spectrometry of fissile and other radioactive materials.

Chemical compatibility and corrosion studies are made to provide materials design information for long-life components and engineering assemblies which include for example the provision of protective coatings. The results of this research are used to monitor the condition of stored weapons and to assess their future life. Surface science forms an important part of this work and in particular electron spectroscopy and secondary ion mass spectrometry show great potential.

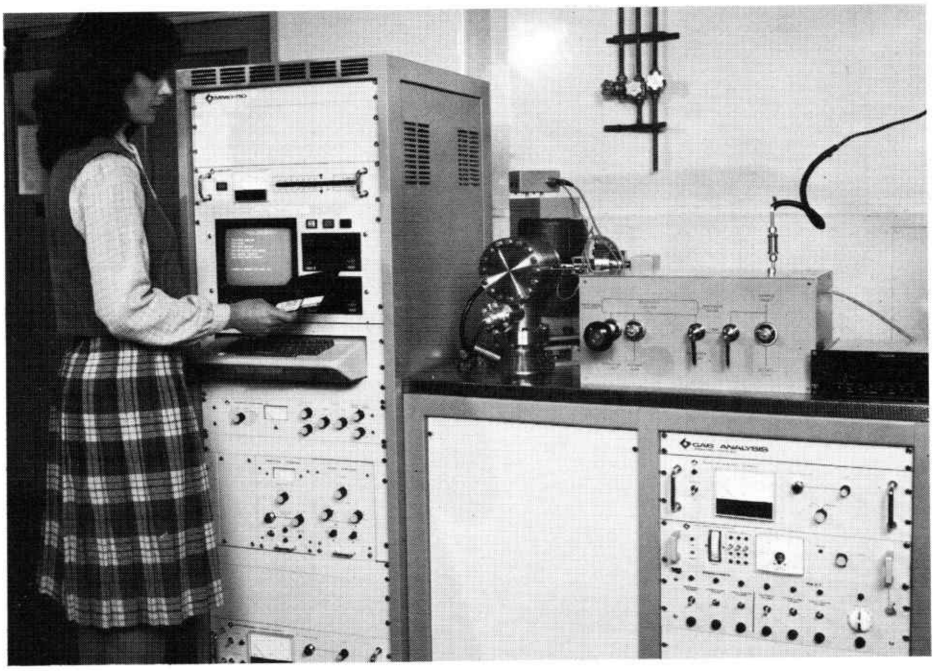
Emphasis is given to a variety of radioactive and toxic materials whose hazardous nature requires the use of special techniques to maintain safe operations.

Materials used in nuclear weapons are controlled by rigorous specifications and extensive chemical characterisation and qualification is required to support the work of the establishment. A wide range of chemical and instrumental methods is used to cover the many different requirements and a continuing research and development programme anticipates future analytical needs. The precise assay of major chemical constituents is important for economy supplemented by multi-elemental analysis for trace impurities met by an appropriate combination of emission and absorption spectroscopy, mass spectrometry, neutron activation and electrochemical techniques. Other analytical methods include chromatography, thermal analysis, particle size analysis and gas extraction and analysis.

The determination of trace organic and radioactive contaminants requires high sensitivity of detection and discrimination. Methods of achieving improvements in sensitivity and in the limits of detection are a continual aim.

A limited amount of new materials development is also undertaken, especially where highly reactive, toxic or radioactive chemicals are involved. The capability to handle substantial amounts of tritium and its compounds is centred on Aldermaston.

Mass spectrometry for the analysis of complex gas mixtures in the study of long-term compatibility of materials.



Explosives Technology

The Explosives Technology Branch is responsible for the development of high explosive compositions, detonators and other chemical

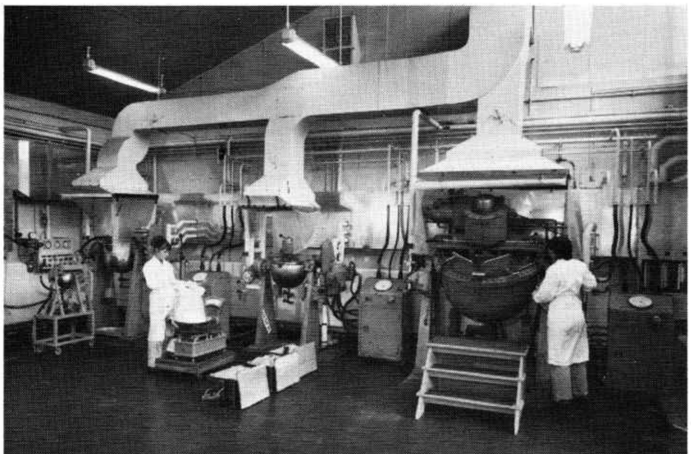
explosive components for nuclear weapons.

Electrically initiated explosive devices (detonators, actuators, squibs etc.) are developed from a basic understanding of the underlying factors to large scale production and proof testing. The study and testing of these devices, often coupled to associated receptor components, is carried out in a range of special chambers, with high and low voltage firing units as well as ultra-fast electronic equipment and cameras which are capable of recording events in the sub-microsecond time scale. Advanced methods of fabrication are applied to the production engineering of component bodies.

A range of high explosive compositions is needed to meet a variety of different requirements, and importance is attached to explosive power, safety characteristics, mechanical and physical properties and reproducibility. The compositions usually consist of a very energetic component (e.g. RDX or HMX) in a binder. Considerable effort goes into the conversion of basic explosive compounds, supplied by Royal Ordnance factories or industry, producing powders with controlled characteristics, mixing them with binders to form moulding powders which are then compacted into charges by isostatic pressing. The study of the rheology of high explosive compositions is essential in obtaining satisfactory processing conditions and mechanical properties.

Organic analysis by high resolution mass spectroscopy.

High performance liquid and gas chromatography units controlled through a microprocessor and used for research into high explosives.



Paste blenders producing moulding powders.

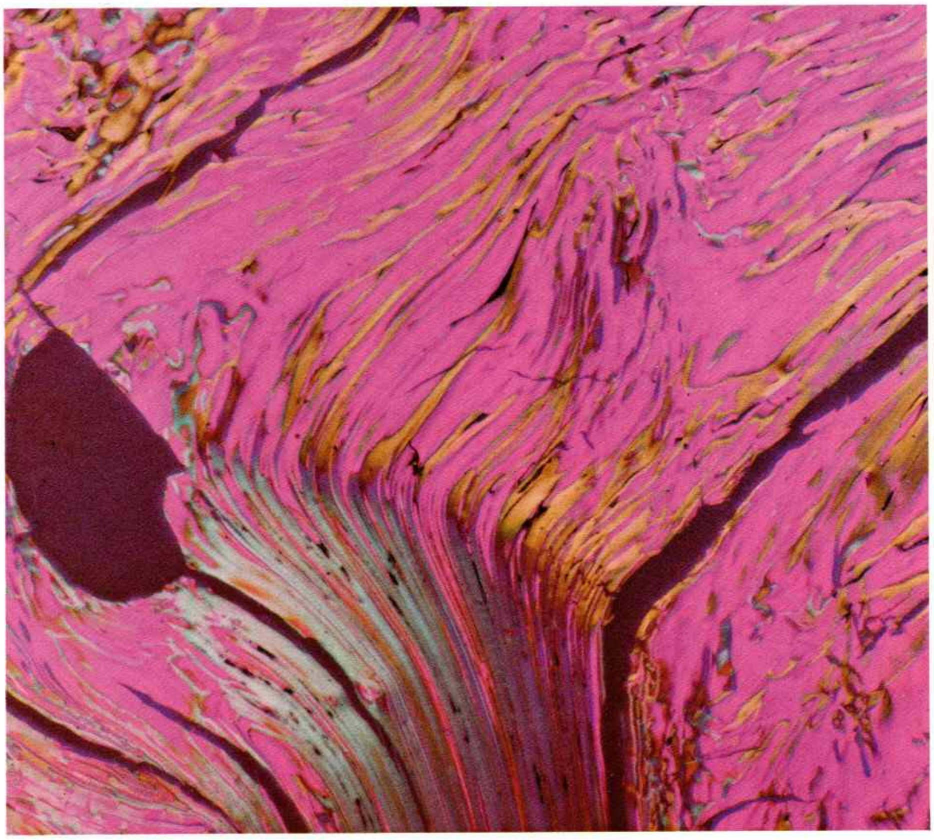
Similarly the initiation and detonation characteristics of high explosives are studied by means of high speed facilities. Safety assessment, i.e. response to different types of stimuli, is of paramount importance and numerous test methods developed at AWRE and elsewhere are used to simulate likely hazards which could arise in manufacture and in Service use.

Mechanical and physical properties of explosives are measured routinely as they affect both safety characteristics and behaviour in given designs. Climatic testing chambers are used to expose units to the temperature and humidity conditions encountered in service.

The accurate machining of complex explosive shapes is carried out using computer numerically controlled machine tools.

Chemical Technology

The support provided by this Division to the establishment's programmes is wide ranging. It can be conveniently grouped into two major areas, one of which is in the field of Materials Science and Technology whilst the other is concerned with Process Development, Plant Design and Plant Operations.



A coke structure from mesophase pitch. Pitch is used to impregnate carbon fibre preforms, carbonised and graphitised to form carbon-carbon structures which are suitable for use for nose tips of missile re-entry bodies. Magnification greater than 1000, under polarised light.

Non-metallic Materials Science and Technology

An important responsibility of the Materials Scientist is the development of practical methods which accommodate the physics intent, and offer solutions which can be engineered into weapon systems. These require a deep understanding of physics concepts with an appreciation of the need for cost-effective solutions in order that efficient production may be achieved. This work is closely integrated with that of Physics Design and Weapon Engineering.

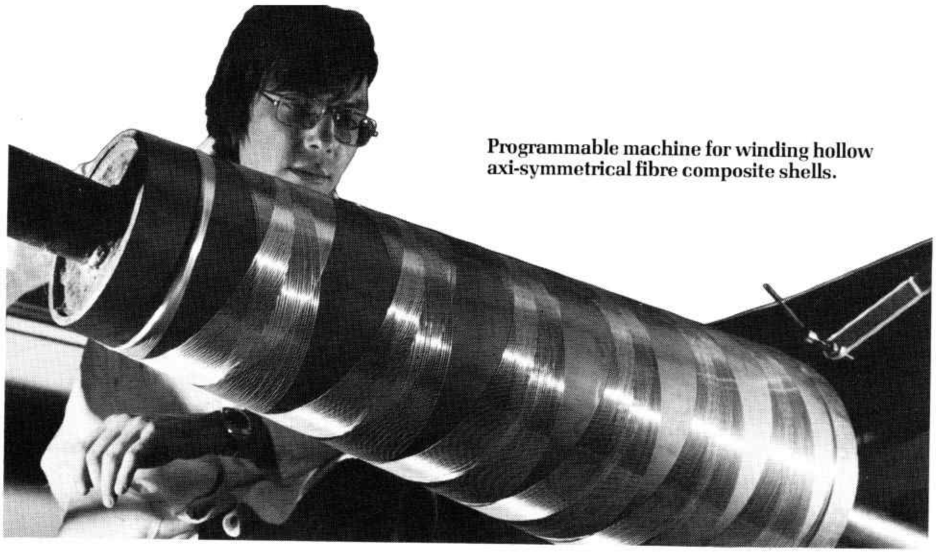
In the materials programme, the Division ensures that the specification and serviceability requirements of non-metallic materials and components used in the weapon systems are met, from inception to production and throughout their service life. This involves a characterisation of new material formulations to achieve specific and closely controlled properties; the development of process and fabrication methods up to prototype production; and the evaluation of compatibility together with the assessment and prediction of the service life of the components. Extensive and unique facilities have been developed to achieve the demands of the programme and strong links maintained with industry to ensure a source of supply for specialised base materials. The materials of current interest are considerable in number, with diverse properties, each developed to suit its own individual specification and requirements. The list includes adhesives, plastics, rubbers, ceramics, oxides, glasses, nitrides, carbides, graphites, carbon fibre-carbon composites and carbon and glass fibre resin composites. Almost as diverse as the number of materials is the range of processes used to fabricate them; this includes plasma spraying, hot pressing, filament winding, injection moulding, chemical vapour deposition, die moulding, resin impregnation and isostatic compaction.

Chemical Engineering and Chemical Plant Operations

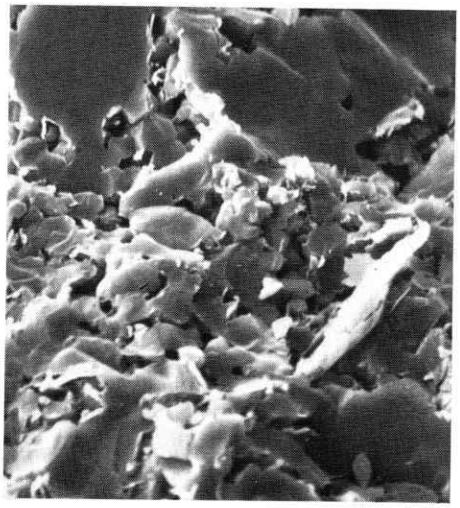
The responsibility for the chemical engineering and chemical plant operations throughout the establishment forms an important part of the Division's work. This ranges from laboratory experiment through process development and plant design to pilot and production scale facilities. The conception and planning of major projects includes the necessary development, plant commissioning and operation.

A major task is a programme of construction of plutonium facilities which also involves the management of consultancy contracts, the preparation of functional specifications and flow sheets, and thorough safety assessments using hazard analysis, operability studies,

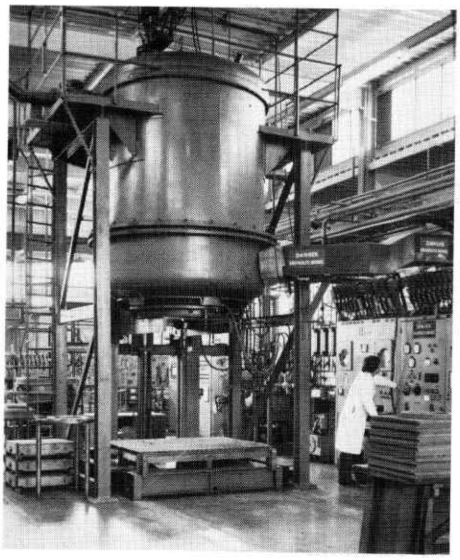
Physical testing of polymeric based materials.



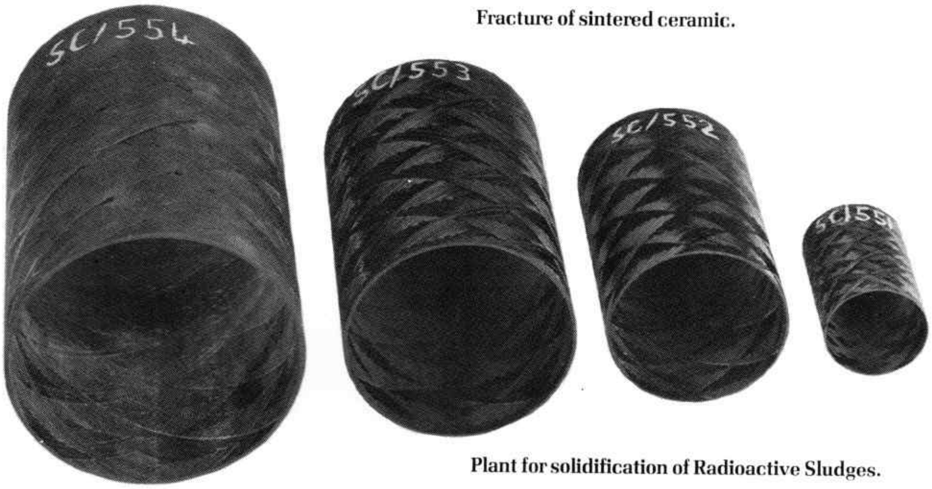
Programmable machine for winding hollow axi-symmetrical fibre composite shells.



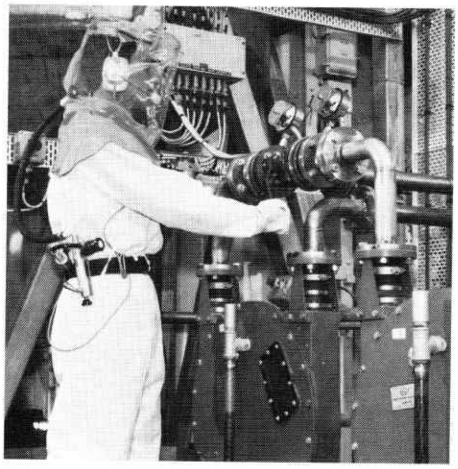
Fracture of sintered ceramic.



Graphitising furnace.

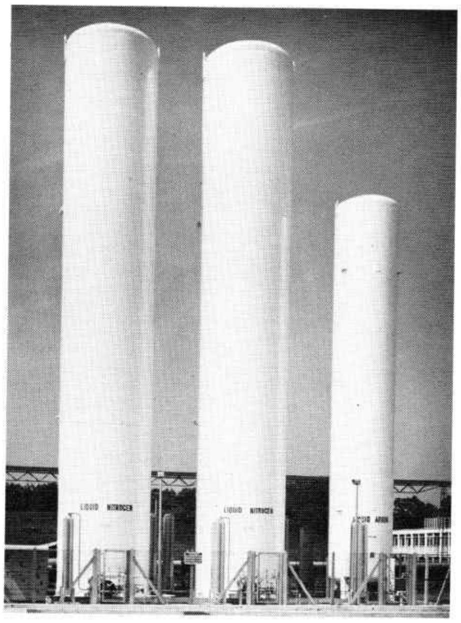


Hollow axi-symmetrical carbon fibre tubes, wound using a programmable machine.

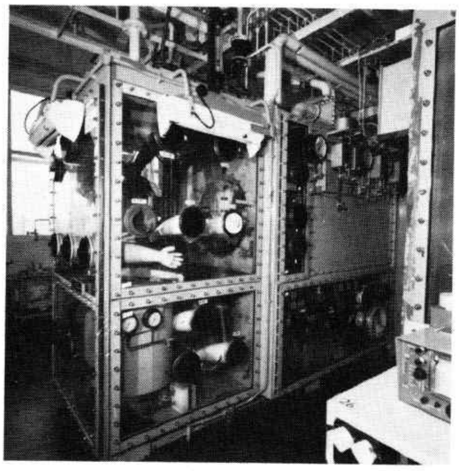


Plant for solidification of Radioactive Sludges.

Evaluation of decontamination methods.



Liquid gas tanks which form part of the Division's charge of chemical plant.



Box for handling radioactive materials.

and other modern analytical methods. The range of materials handled extends from the conventional through radioactive materials to advanced composites, and has led to the development of many novel processes.

The operation of gas purification plants throughout the establishment is supervised by the Chemical Technology Division. This ensures that the work-box atmospheres are of sufficiently high purity to permit the processing of radioactive, toxic, pyrophoric and chemically reactive materials and the treatment of radioactive effluents and residues. In all these operations there is a special emphasis on close process and quality control which requires a high degree of skill in organisation and management and the application of resource and costing analysis together with the use of modern management and forecasting aids.

Other important commitments include the development of techniques for decontamination and decommissioning of radioactive plant, together with the treatment of radioactive effluents and the recovery of valuable materials from residues and wastes.

Metallurgy

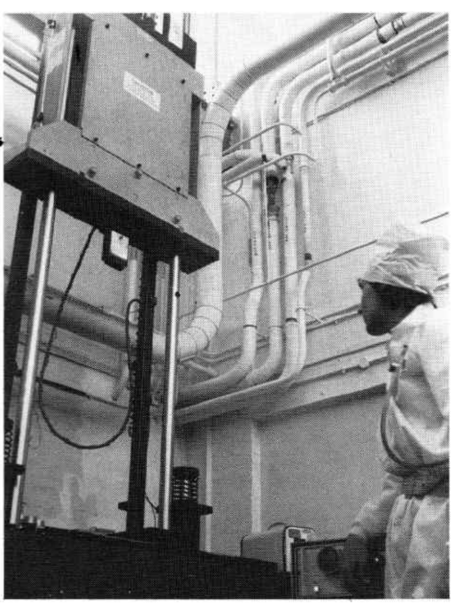
The Metallurgy Division undertakes research and development on plutonium, uranium, beryllium and certain ferrous and non-ferrous metals of particular importance for warhead design; it also maintains the capability to produce, economically, consistent and reliable components which have the expectancy of a long service life in specific environments.

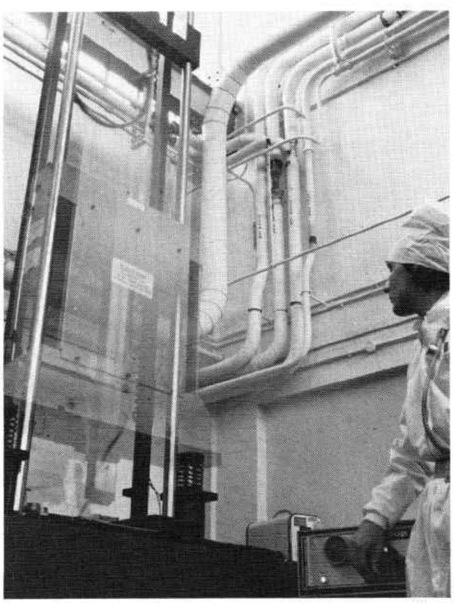
Research and development generally entails improving the mechanical properties of the materials, in some instances up to very high strain rates, and includes topics such as heat treatment and fracture toughness, in addition to normal mechanical testing. Similar work also forms part of a non-nuclear programme to develop armour penetrators. Components are fabricated using a wide range of processes including vacuum casting, forging, rolling, deep drawing, extrusion and spinning. Powders are consolidated under vacuum using either cold or hot pressing methods and the Division also operates a plasma spraying unit. Joining processes employed in assembly work comprise electron beam welding, vacuum brazing, inert gas welding, and pressure and diffusion bonding. New fabrication processes are introduced after careful evaluation, and existing methods are subject to constant development.

Electron beam welding equipment for joining uranium.

Corrosion studies are important for the achievement of a long service life; these involve the assessment of compatibility of metals with other materials in the solid, liquid or gaseous state. Stress corrosion, corrosion fatigue and hydrogen embrittlement are important aspects of this work. In some instances protective measures such as coatings are required. Development of these is therefore a continuing requirement. Electrochemical deposition, evaporation and ion-plating methods are used.

A drop tower impact machine used for the dynamic testing of uranium. The one ton drop weight can subject large specimens to high strain rates to enable the impact characteristics to be studied.

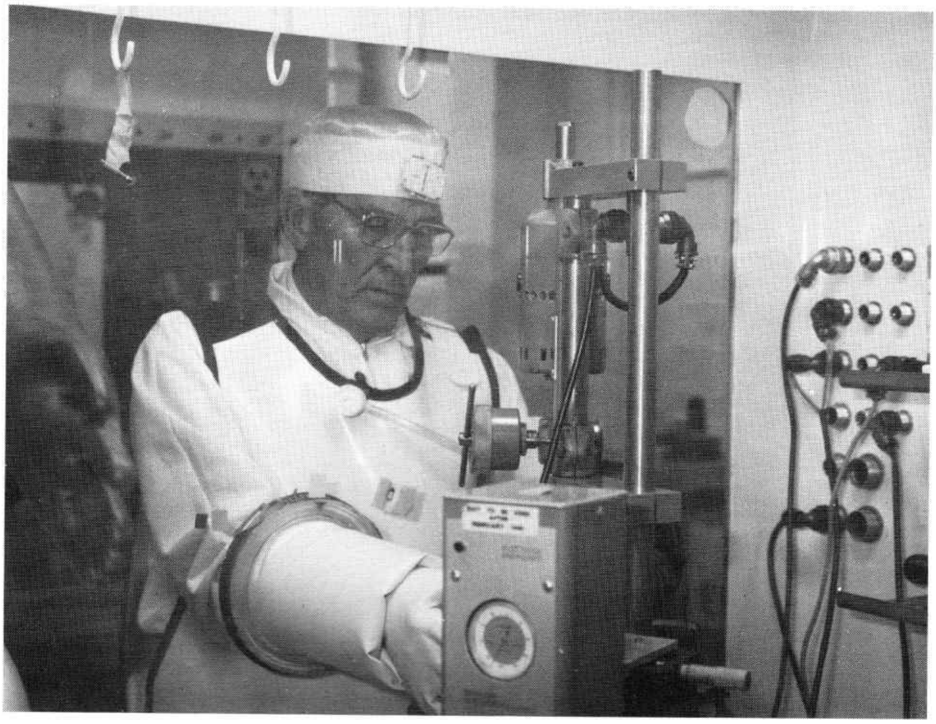




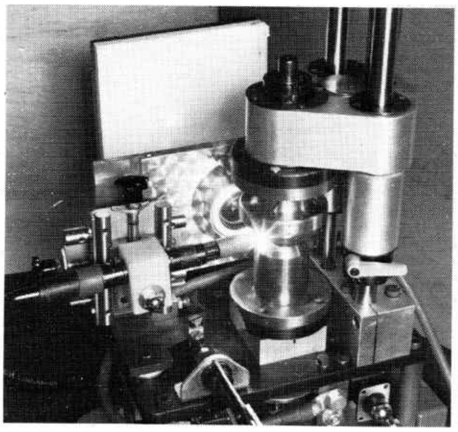
Specialised techniques of examination and analysis on the micro-scale are available to support the work described in this section of the brochure. Electron microscopy includes scanning instruments and electron microprobe analysers: X-ray diffraction and quantimet analysis are used. A laser microprobe analyser (LIMA), has recently been installed. Though really intended for light element work, it is proving valuable for determinations of all of the elements.

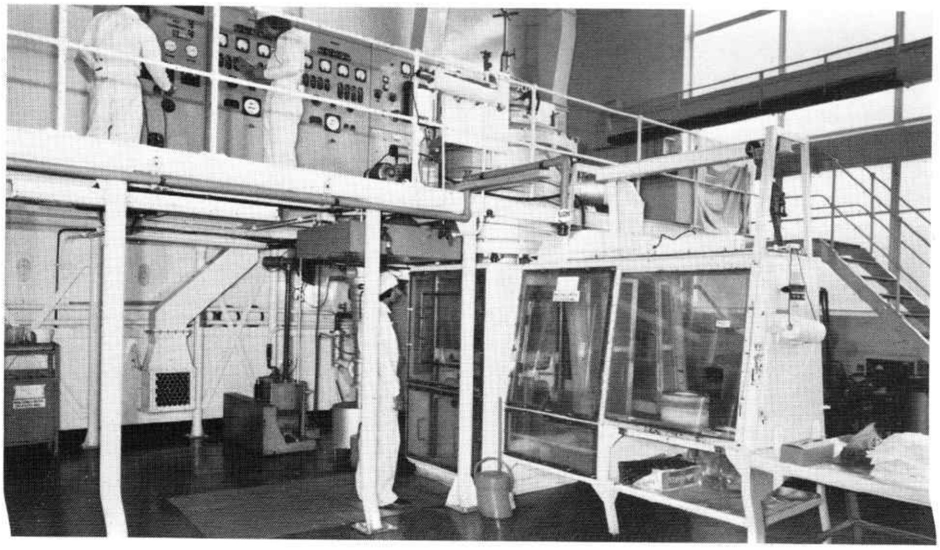
The Division's facilities are very extensive. A new building for plutonium work is being constructed using the latest proven design principles. It will replace older plant which though still satisfactory does not easily lend itself to the efficient use of modern radioactive handling systems.

Glove box working position for handling radioactive metals.

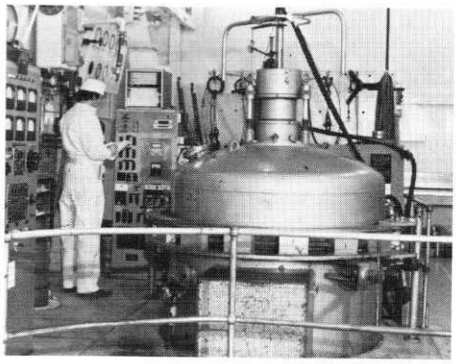


Automatic welding machine designed specifically for use in a glove box environment. Projections of the arc image and the weld silhouette on the screen enable precise control of the weld contour to be achieved.



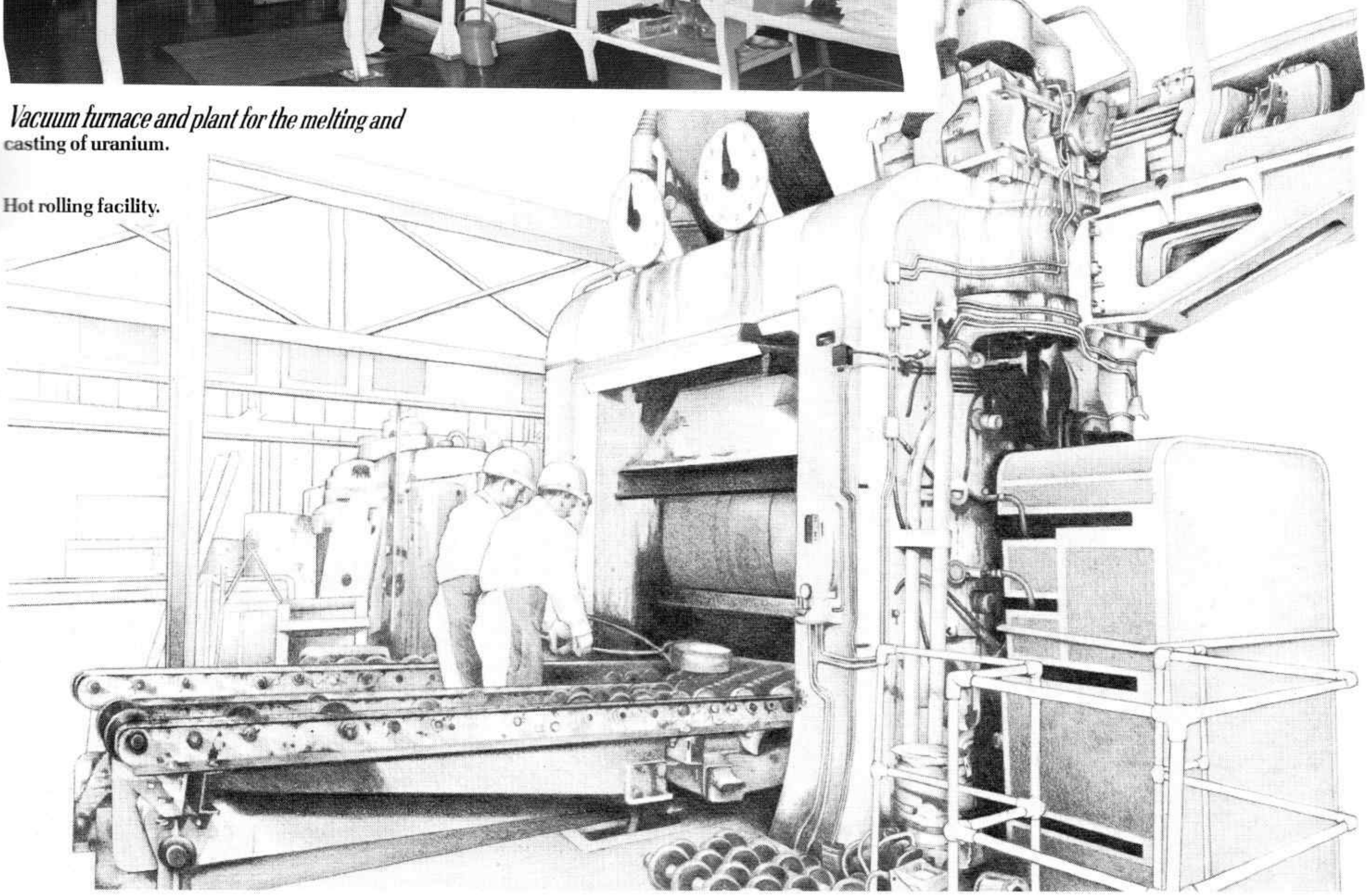


Vacuum furnace and plant for the melting and casting of uranium.



Hot pressing unit used for the vacuum consolidation of beryllium powders.

Hot rolling facility.



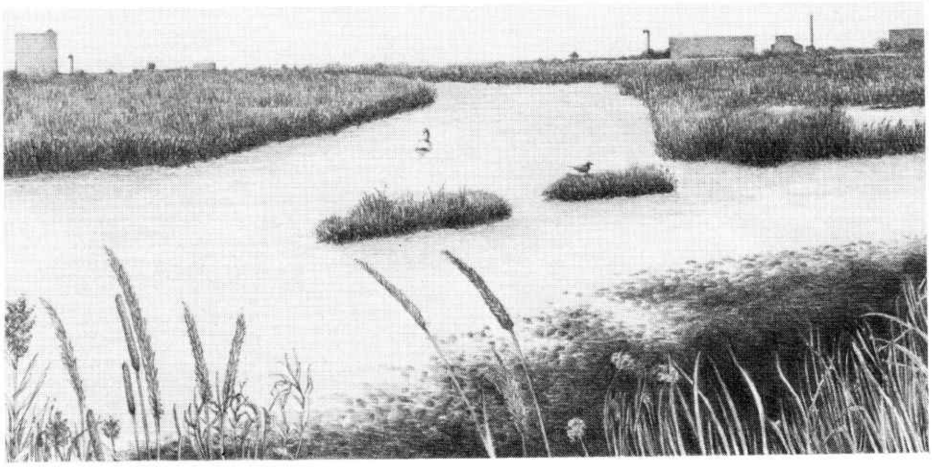
Foulness Ranges

AWRE Foulness is a self-contained out-station situated near Shoeburyness at the mouth of the River Thames. The secure perimeters of this 2,000-acre area of marshland offer protection to a wide variety of bird life.

The Foulness ranges can fire explosives and pyrotechnic charges up to the maximum permitted in the United Kingdom, and provide facilities for studying the complete spectrum of explosive effects from both conventional weapon systems and, by simulation, the effects obtained from a nuclear explosion.

Trials laboratories and equipment are available to study accurately the response of structures to shock and blast waves and thermal radiation, and thereby to validate calculations of models. The Division assesses the lethality of missile warheads and ammunition for the three Services.

Foulness has always been concerned with the effects of nuclear weapons. Since the cessation of atmospheric nuclear tests by the major powers, the Division has pioneered methods of simulating and measuring the effects of large explosions on a reduced scale which is quiet and cheap. The precise pressures and loads are achieved by using comparatively small explosive charges in conjunction with scale model targets. The models are locally made and are frequently elaborate constructions of metal and reinforced concrete. The effects of the explosion are studied from various angles by methods which include high speed photography at millisecond time scales.



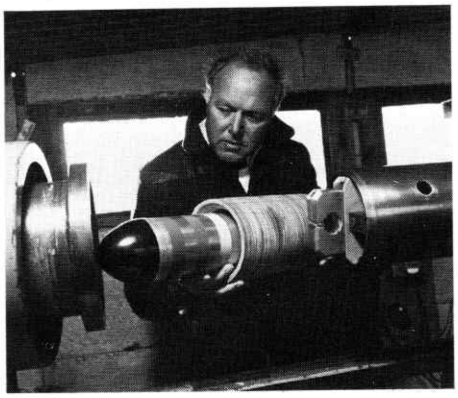
The ranges occupy an area of marshland which also supports a variety of bird life.

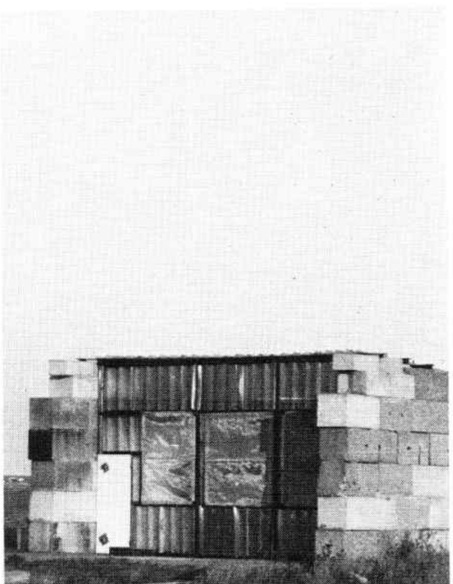
Many of the station's facilities have been designed and developed within AWRE, and represent a high level of scientific and technological achievement; for example, there is an explosively-driven air blast tunnel in which large items of military equipment can be subjected to effects similar to those experienced in an atomic explosion. It consists of a shock tube more than 500 feet long in three stepped cylindrical sections of increasing diameter. The item of equipment under evaluation, e.g. armoured vehicle, naval masthead antenna, or radome, is mounted in the test section. The explosive charge at the smaller end of the tunnel is made from detonating fuze wound spirally round a polystyrene former to produce blast wave patterns of known specific peak pressure and duration. As the explosion takes place the confining nature of the tunnel creates the blast effects, and data on the behaviour of the test item are obtained from recording apparatus in adjoining buildings, and in mobile trailers which can be moved up to the tunnel.

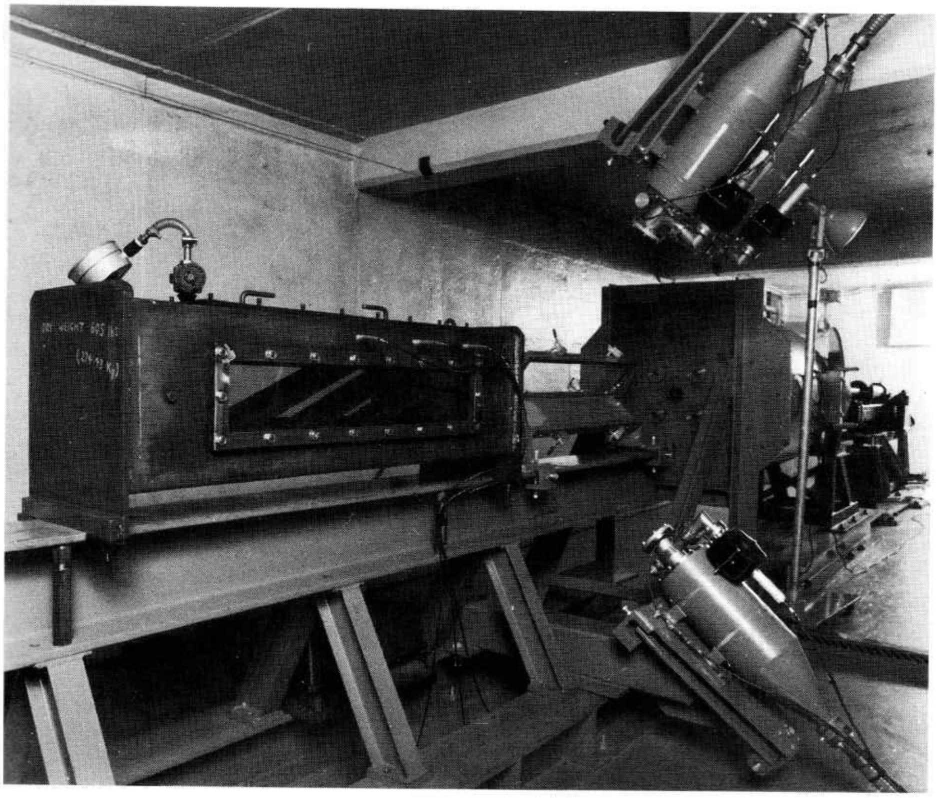
An additional section of yet greater diameter has now been added increasing the length of the tunnel to more than 650 feet.

Another facility with a good record of achievement is a dual flash radiography system, SWARF. Transient events, such as the

Deformable projectile simulating aircraft impact being loaded into compressed-air launcher.

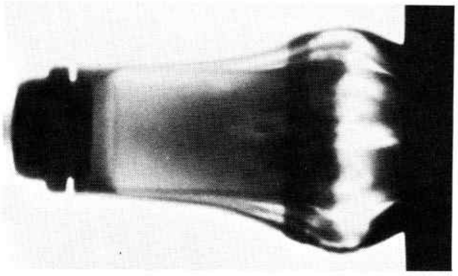


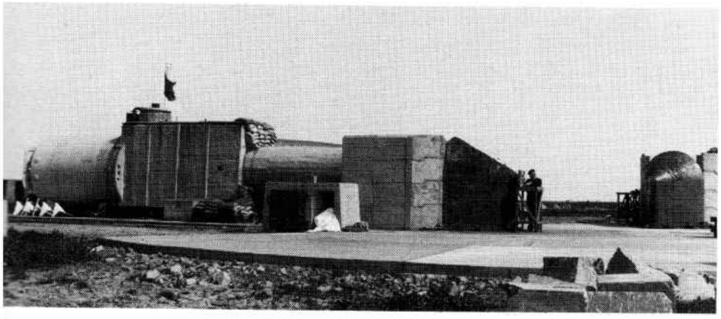




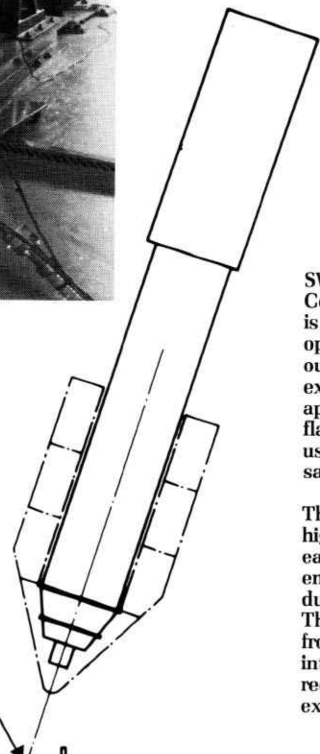
Flash X-ray camera heads in the ballistics laboratory where the high velocity launch of projectiles and target penetration characteristics are studied.

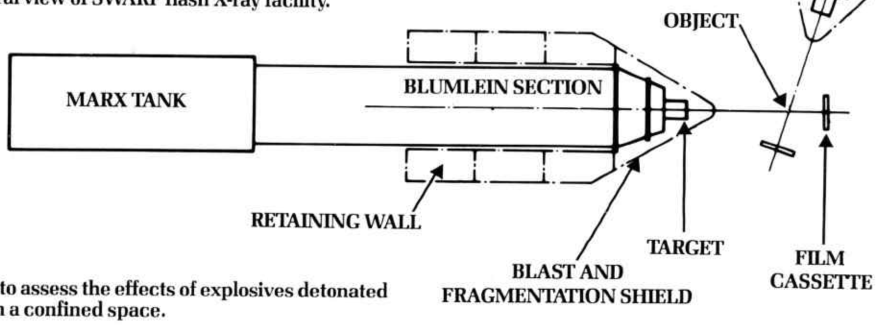
SWARF radiograph of detonating flat-ended projectile showing rupturing case.





General view of SWARF flash X-ray facility.



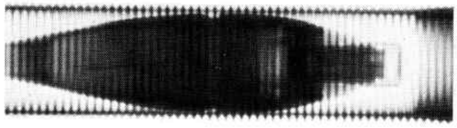


SWARF

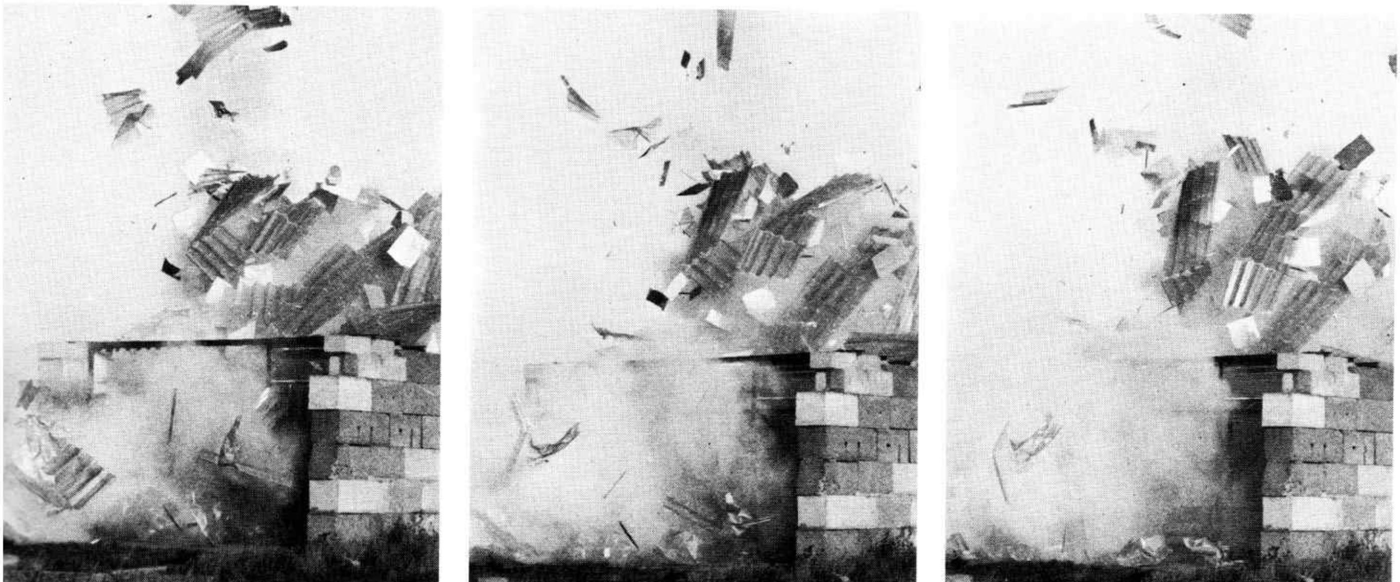
Conventional X-ray equipment is designed for continuous operation with limited dose output and relatively long time exposures. A quite different approach is used in the SWARF flash X-ray facility which is used to study events moving at say 10 mm/μs.

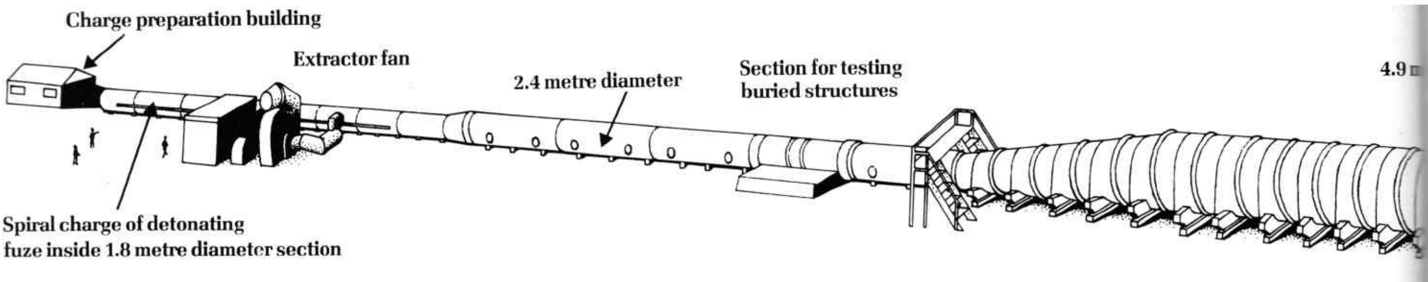
The equipment consists of two high-voltage impulse generators, each of which release a stored energy of 40 kilojoules over a duration of 60 nanoseconds. They are fired independently from different angles at a time interval chosen to suit the requirements of the individual experiment.

An example of the power of the flash X-ray is shown, where a mortar shell is 'frozen' whilst travelling at high velocity along its finned firing tube.



Trials to assess the effects of explosives detonated within a confined space.





Arrangement of Foulness Blast Tunnel

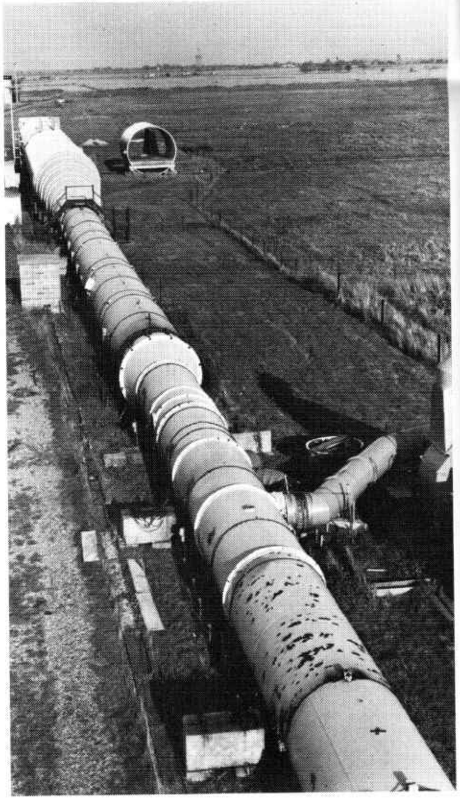
penetration of an explosive device into armour or other high strength material, can be recorded through thicknesses up to the equivalent of 18 cm of steel. Since the exposure time is of the order of nanoseconds, SWARF can 'freeze' detonation phenomena and explosive jet propagation in pictures taken from two different angles and sequenced in time at intervals of microseconds.

Pressure measurement is central to the Foulness task; there has been much work on the development of devices to measure accurately the effects of various pressures in solid, liquid and gaseous media.

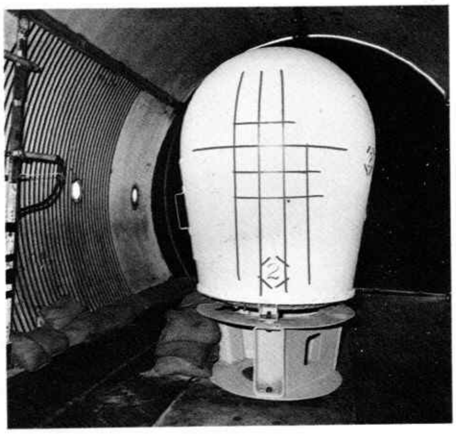
Techniques available to support the UK conventional weapons research and development programme include facilities for rocket in-flight studies and warhead fragmentation trials; instrumentation arenas for examining the performance characteristics of directed energy and blast warheads; and ranges (both open and enclosed) for studying the in-flight and terminal ballistics of kinetic energy projectiles. Mobile services are available to enable X-ray, high speed and conventional photography to be undertaken on any part of the station or at other ranges in Britain and overseas.

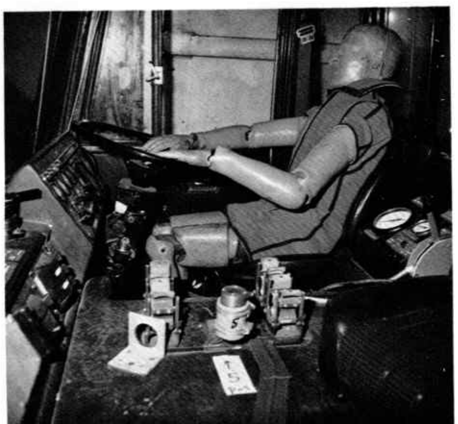
AWRE Foulness has a wide range of supporting technical and administrative services. It operates an Apprentice Training Scheme (up to 20 at any one time). Socially and recreationally it is a self-contained unit with yachting, flying and Civil Service clubs in the area, and employees and their families have the advantage of living within reach of several East Coast holiday resorts.

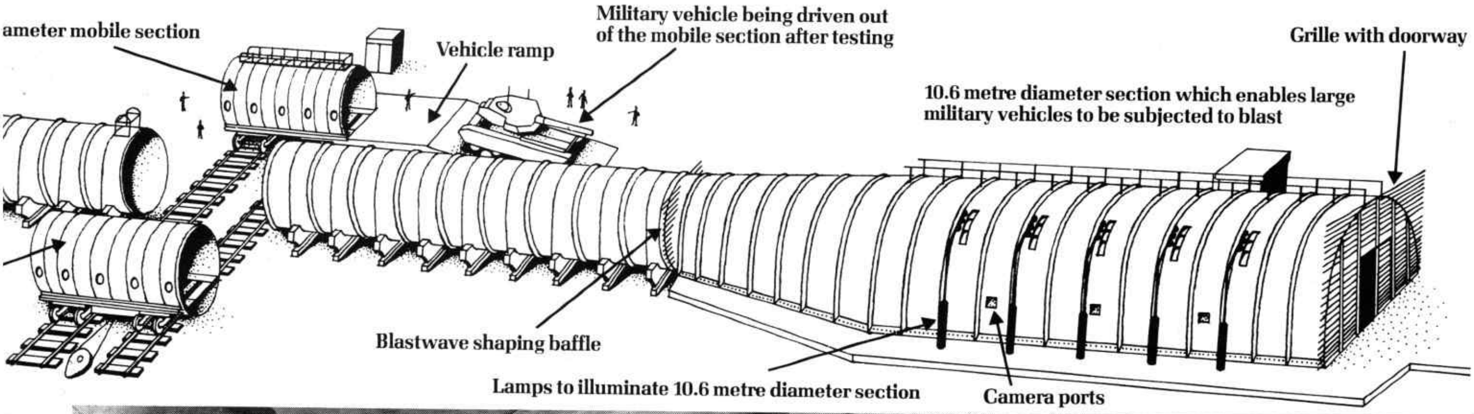
During the past few decades, the unique facilities and the expertise developed at Foulness have found many outlets of benefit to industrial and governmental authorities. These include investigations into such hazards as the sudden failure of pressure vessels, studies of the structural integrity of gas, chemical and oil storage plants and pipelines, and surveys of the damage and pressures experienced in disasters such as those at Flixborough and Ronan Point. Much of this work has been performed on behalf of the United Kingdom Atomic Energy Authority, in particular, most of the experimental work on the safety of reactor structures was conducted at Foulness. At present a major customer is the Central Electricity Generating Board.

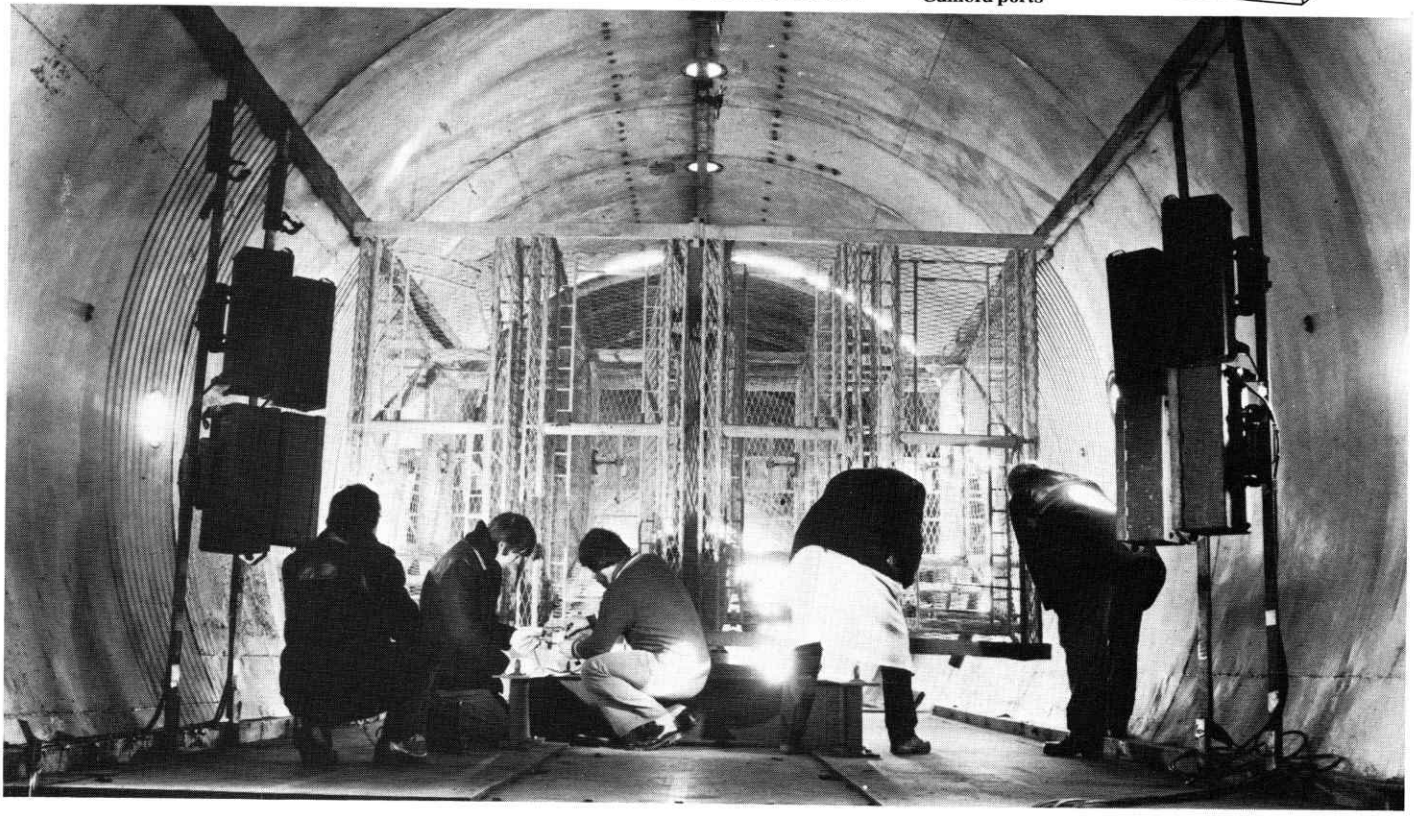


The blast tunnel accommodates a variety of military equipment.






ameter mobile section
Military vehicle being driven out
of the mobile section after testing
Vehicle ramp
Grille with doorway
10.6 metre diameter section which enables large
military vehicles to be subjected to blast
Blastwave shaping baffle
Lamps to illuminate 10.6 metre diameter section
Camera ports



Engineering

The Engineering Department, under the Chief Engineer comprises the Facilities Engineering Division, Engineering Workshops Group and Quality Assurance Group. It is responsible for the design and construction of new plant and buildings, all maintenance work, engineering operations, mechanical and electronic workshops, machine tools and metrology services, engineering support to scientific divisions and apprentice training.

FACILITIES ENGINEERING DIVISION
This Division embraces the main engineering disciplines, viz. civil, mechanical, electrical, structural and instrumentation, and undertakes a very diverse range of tasks.

The Materials Engineering Group, staffed mainly by professional engineers, designs and develops equipment for processing, fabricating and machining radioactive and special materials. 'State of the art' manufacturing technology, numerically controlled and conventional machine tools, jigs and fixtures all feature in the special materials workshops managed by the Group.

The Services and Construction Group is managed by professional engineers. It operates the site power station and electrical distribution system, maintains all the radioactive, toxic, conventional and complex experimental plant, buildings and services. The diverse operational tasks require a large number of skilled craftsmen and semi-skilled workers together with contractors, in a variety of trades. In addition new construction of complex plant in a variety of specialised environments is carried out by this Group.

The Project Engineering Group manages the provision of capital facilities for AWRE. Some 80 per cent of the staff are professional engineers in the main engineering disciplines, since most projects require a multi-disciplined approach. Consultant engineers are employed under the direction of the Project Engineer and complex schemes up to several million pounds are undertaken, frequently involving 'state of the art' engineering. The feasibility studies required, often involve specialist research organisations and universities. Project engineers are individually responsible for complete schemes involving estimating, design, control of finance, planning, safety and reliability assessments, construction and commissioning.

Close tolerance assembly.

In summary the Facilities Division provides and maintains the specialised facilities of plant, equipment and services necessary for the wide range of research work undertaken by AWRE. It works closely with scientists of all disciplines and ensures that sound engineering contributes effectively to the establishment's programme.

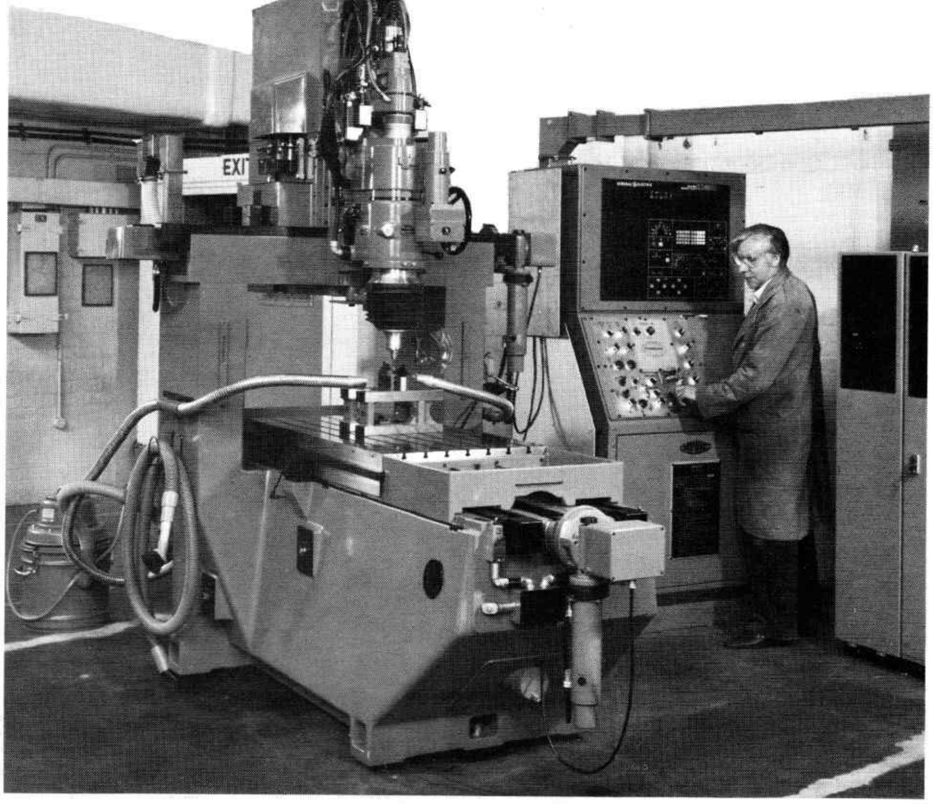
ENGINEERING WORKSHOPS
This Group, staffed by professional and industrial grades, is virtually a self-contained manufacturing unit, its capabilities ranging from precision engineering manufacturing to electronics assembly, development and testing. There are five main sections or areas of activity.

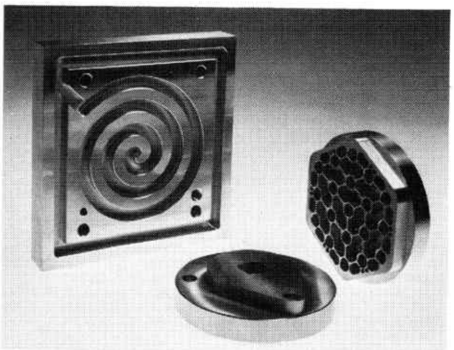
Manufacturing Workshops
These engage in precision and general engineering production to meet the establishment's manufacturing and research and development requirements. A range of trade skills are employed including instrument making, electronic craft, turning, milling, fitting, grinding, sheet-metal working, welding, etc., backed up with the versatile machine tools and equipment. Numerically controlled machine tools and high-precision copying machines increase capacity for the manufacture of complex components.

Machine Tool Services
The procurement, installation, maintenance and overhaul of the establishment's machine tools is the responsibility of this Section. It covers all types of machines and control systems including sophisticated numerically controlled systems. A specialist machine tool staff gives an advice and guidance service to all Departments and there is a programme of design, development and construction of special purpose precision machine tools and equipment in support of the establishment's manufacturing programme and development tasks.

Instrument Services
This Section is responsible for electronics support for a complex environmental test facility involving systems development, instrumentation and specification preparation and testing. A service is provided for the purchase and maintenance of electronic instruments and test equipment for site use and for advice and guidance on the suitability of equipment. Additionally, development work is undertaken on a variety of projects, including specialist communications and control systems. The Section also has a specialist plastics group

Moore continuous path jig grinder with GEC 1050 CNC control which can achieve a positional accuracy of 0.0075 mm and grind at speeds up to 175,000 rpm.

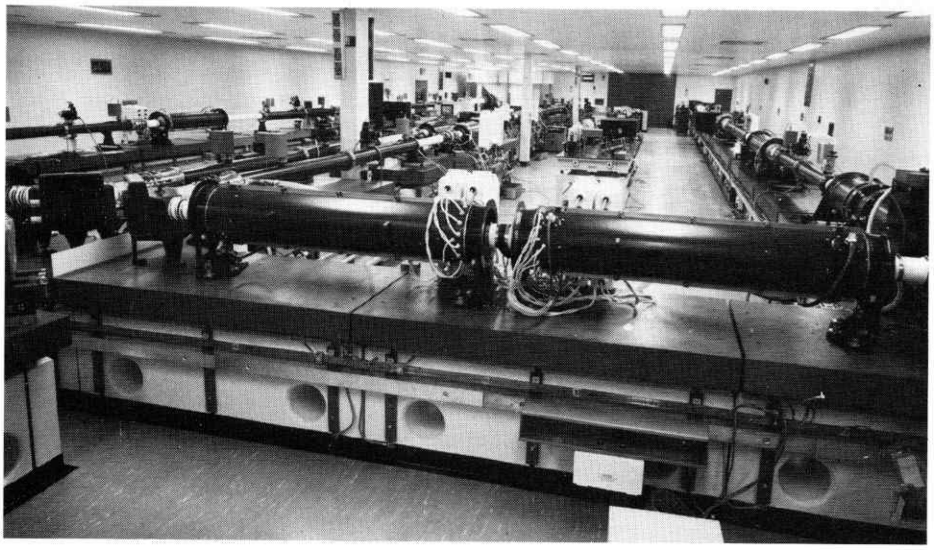




Examples of complex work produced by numerically controlled machine tools.

The building, mechanical and electrical services for the high power laser facility HELEN, were the responsibility of the Division.

Centre right. Building starts. Steel erection in progress.

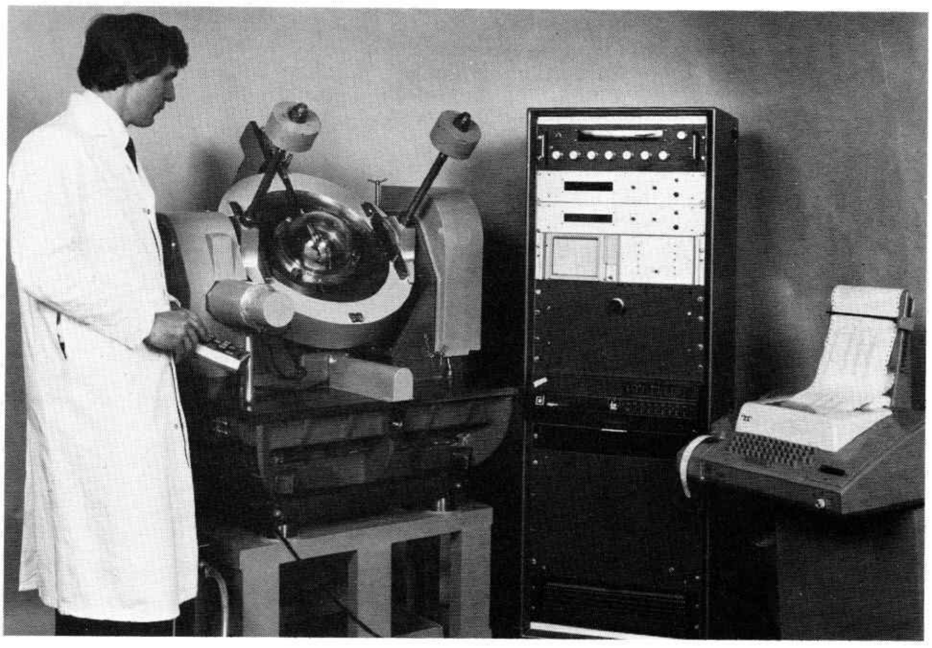


The completed laser hall. The necessity for exceptional stability of the base of the building and close temperature control of the highly filtered clean air supply were exacting demands in this project.

capable of undertaking development and prototype work. It provides further advice and guidance on plastics technology and in the use and application of modern plastics materials.

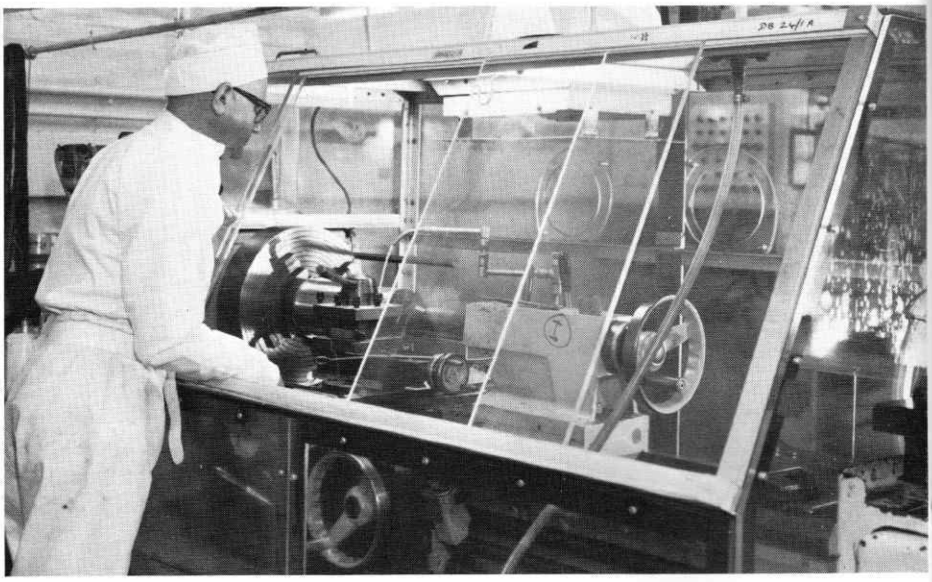
Engineering Techniques and Work Study

A small Section of professional engineers and technicians provides the facility for engineering studies in manufacturing techniques and processes, and the management of other technical projects.

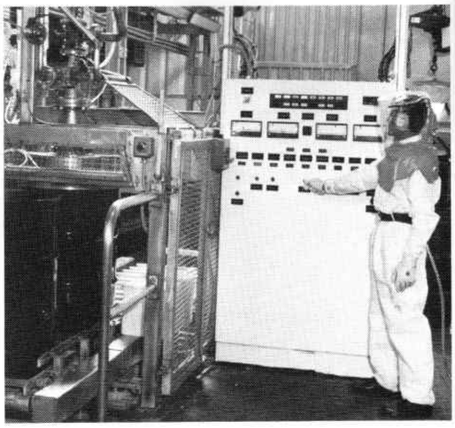


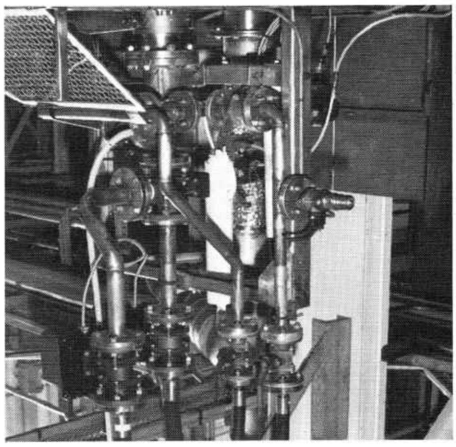
Rotary contour gauge for the measurement of non-angular components.

The provision, installation and operation of all engineering equipment at Aldermaston is undertaken by the Division.
Here a lathe operator is turning uranium in an air extraction box in one of the buildings for handling radioactive materials.



Engineering apprentices in the training centre workshop.





Process for the solidification of sludge from low level radioactive liquid effluent.

Top
Drum filling station.

Above
Sludge gun and interlocking controls.

Apprentice Training

There is an Apprentice Training School for first and second year training of Craft Apprentices undertaking a four year apprenticeship. Some 160 school leavers are normally under training in a wide range of trade disciplines. Additionally, practical training and projects are provided for Graduate and Student Engineering training.

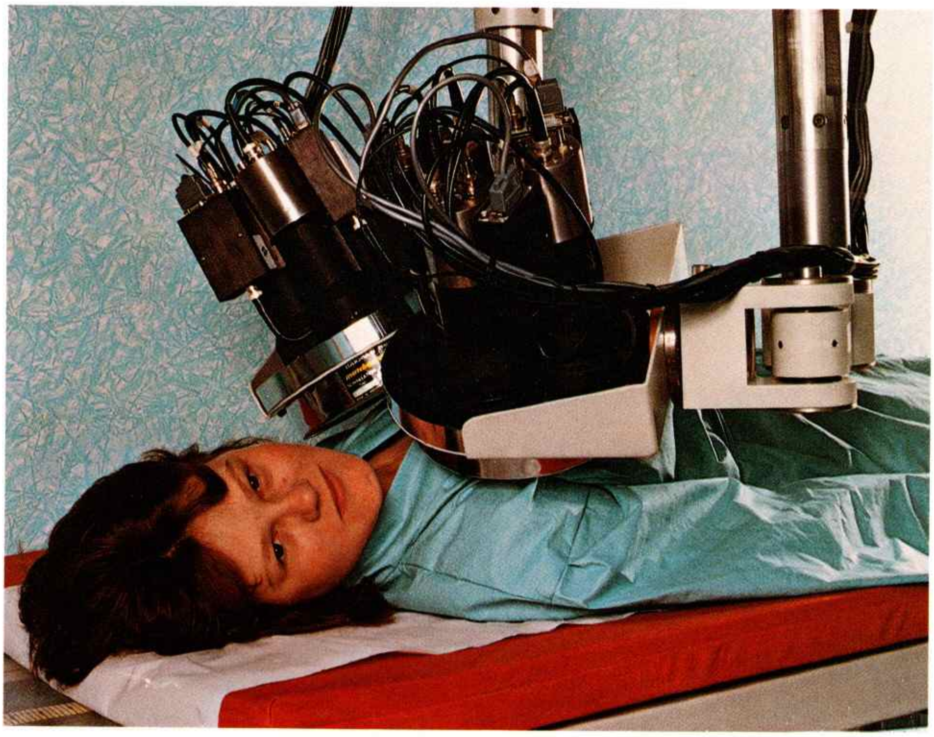
QUALITY ASSURANCE

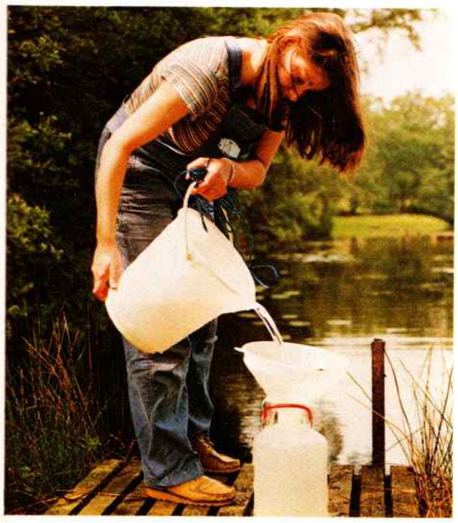
A senior professional engineer is responsible for quality assurance activities throughout AWRE. He has a team of professional and technology grades of mechanical, electrical and metallurgical disciplines deployed as complementary teams of quality assurance engineers and control inspectors in all working areas. They are supported by a central planning and record office and five laboratories. The latter are concerned with high-precision experimental measurements of dimensional, metallurgical and physical properties of engineering components. They maintain master reference measurement standards and are responsible for the development of special purpose quality control equipment required for metrology, electronic and non-destructive testing purposes arising from inspection areas.

Unorthodox problems are encountered through the extreme integrity required in nuclear work and involve sophisticated techniques in active, toxic and explosive environments, often calling for remote and automated handling. Commercial standards and practices need to be considerably refined or original techniques developed for the establishment. Collaboration wih scientific, project design engineering staffs and manufacturing centres is maintained to assure appropriate quality standards.

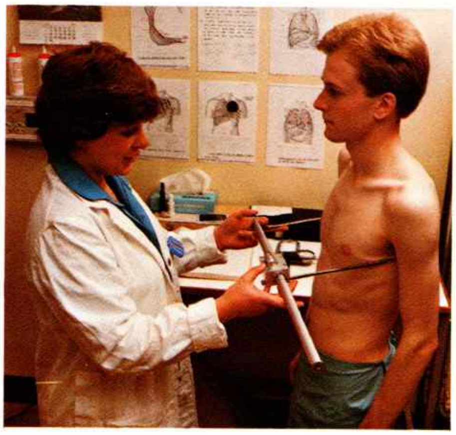
Health and Safety

Although the responsibility for maintaining safe working conditions rests with all branches of management, the formal aspects of health and safety advice are provided by the Safety Division which is under the control of a senior scientist who is a member of the Board of Management of AWRE. The establishment is a major employer in the locality with a complex of industrial and scientific facilities. In some areas radioactive materials are used, but most of the potential hazards are common to any industry. Chemicals are widely used and a vast range of electrical and mechanical equipment is in operation.





Taking a routine surface water sample. Locations at AWRE and outside the establishment are monitored regularly.



An assessment of radiation from within the body is carried out at regular intervals on personnel who work with radioactive materials.

The measurements are made using a whole body monitor. In addition biological samples are analysed for radioactive substances.

To derive the greatest accuracy from the whole body monitor, account must be taken of the body weight, size and chest wall thickness of the subject.

Medical Division

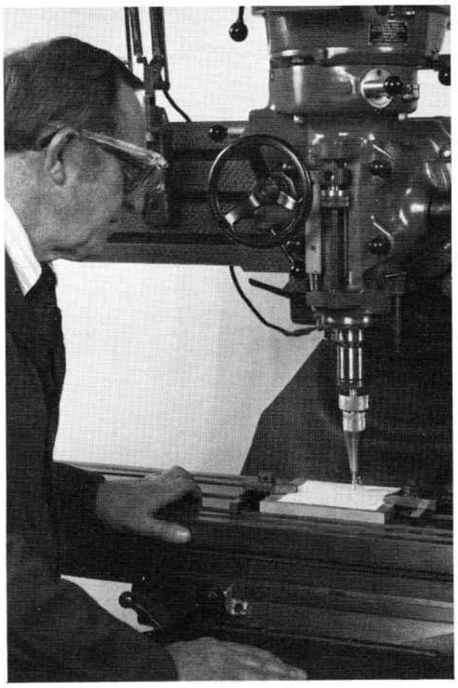
There is close co-operation between Safety and the Medical Division. The latter is an autonomous body which is responsible to the Director of the establishment. A full occupational health service is provided, staffed by medical officers, nursing staff and supported by a pathological laboratory and X-ray department. The service provides toxicological advice to Divisions as well as overseeing the health of employees and carrying out epidemiological research.

The exterior view of the buildings of the Medical Division.

The function of the Safety Division is to assist in assuring the protection of the workforce and general public by giving specialist advice and monitoring the results of operations on the site. Over the last thirty years there has been considerable expenditure, effort and accumulation of knowledge in the use of nuclear radiation and materials. The nuclear industry in this country has a safety record that compares most favourably with that of any industry. Some of the philosophy and techniques developed and used so successfully in radiological protection can usefully be extended to other areas of occupational health and safety.

Experts in radiological protection, nuclear, chemical, industrial, mechanical, electrical and explosives safety, work together to provide an integrated multi-disciplinary approach to the subject. Professional advice is given to cover work involving a wide range of technologies; from conventional plant and machinery to complex experimental systems. For each new project or facility, consideration of safety is an important aspect during planning, construction, operation, maintenance and ultimate disposal. Modern statistical analytical techniques are used at the design stage to identify and minimise any hazard. As a further safeguard, a safety assessment is made by an impartial board containing experts from outside AWRE which advises the Director of the establishment.

Surveillance of the safety aspects of facilities is continuous and is the special task of the Division's Facilities Safety Superintendency. It checks that equipment and practices are complying with statutory requirements, it is responsible for keeping various obligatory records and it is tasked with ensuring that operations on site meet the requirements of a range of regulatory bodies. These include the Health and Safety Executive, the Department of the Environment, the Ministry of Agriculture, Fisheries and Food, the Department of Transport and the Department of Health and Social Security. The Recommendations of the International Commission for Radiological Protection are a cornerstone of the radiological protection programme. AWRE is represented on a number of safety committees which deliberate on the criteria for the design of new installations. An important aspect of the Division's work is to oversee the quality and standard of safety training.



As well as advising on the specialist fields of radioactivity and toxicity, the Division is equally involved with ensuring that conventional safety methods are applied and standards maintained.

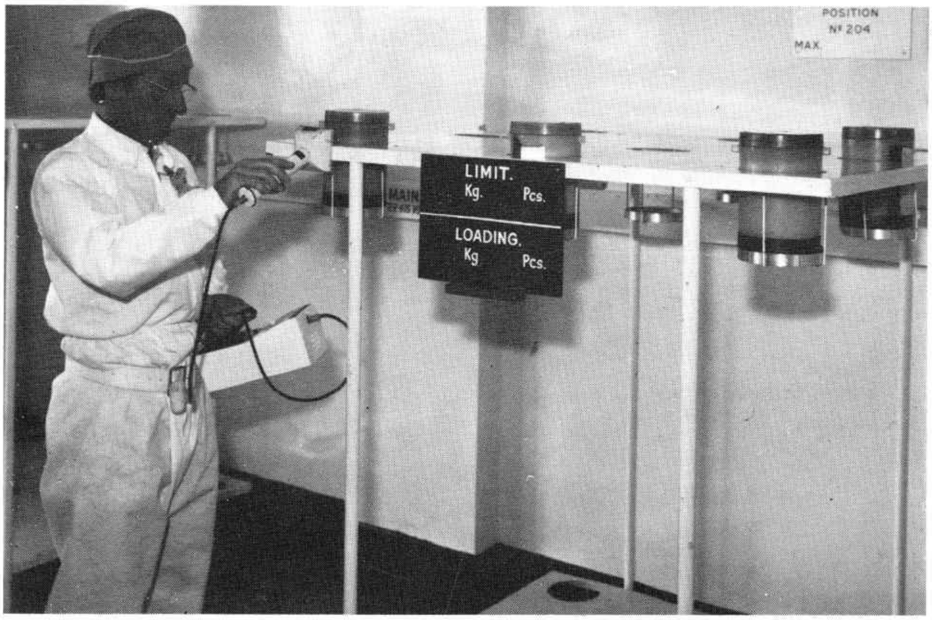
Fully equipped mobile safety support laboratory.

The work of the Safety Division is an essential part of the day-to-day activities of the establishment. The Personnel Safety Superintendency provides and supervises the AWRE radiological protection services. It is called to give professional advice on the precautions to be taken during manufacture, maintenance and repair processes involving radioactive materials. Its staff perform a wide range of survey work, measuring radiation and air and surface activity levels, in laboratories and workshops. This organisation also provides personal dosimetry and bioassay services to AWRE and some other establishments. There are two whole body monitors that are used for in vivo screening of staff who work with radioactive materials. Occupational hygienists provide an advisory and monitoring service to assure safe handling of toxic materials. Advice is also given on: industrial noise and vibration, non-ionising radiation, protective clothing and respiratory protection against dusts, vapours and gases.

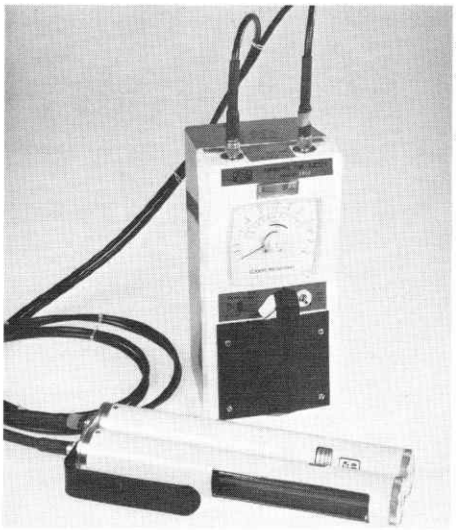
Environmental survey work is carried out both on and off the site so that the Director can be satisfied that the effect of the site on its surroundings is minimal and of the order of the normal background levels.

Research and development work is carried out in relevant areas to improve safety methods. In electronics design, the latest technology is applied to new nuclear instrumentation. A number of such designs are manufactured commercially under licence and royalties are paid to MOD. Particular attention is being paid to computer linked hazard alarm systems and to intelligent instrumentation which can alert operating staff that abnormal conditions are developing before they become hazardous. An electronics team is responsible for the procurement, testing and maintenance of a very large range of safety instrumentation.

The formation, behaviour and identification of radiotoxic aerosols is studied using laboratory facilities that can simulate a variety of accident conditions. Computer models based on laboratory and field experiments are used to predict the possible consequences of an



Routine monitoring of contamination levels within an active area.

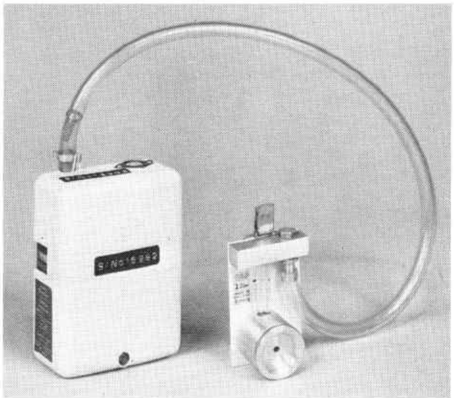


A special gamma compensated monitor developed to allow beta radiation to be measured in the presence of gamma radiation fields.

atmospheric dispersion of toxic material in particulate form. These are used to predict the outcome of a range of hypothetical events including, for example, fire or explosion. The Facilities branch provides a nuclear instrument standards calibration laboratory associated with the National Calibration Service co-ordinated by the National Physical Laboratory at Teddington, which includes the MOD Secondary Standards Centre.

The Division is responsible for giving appropriate scientific advice and assistance to other government departments and to HM Forces on matters relating to nuclear defence and the operational safety of weapons systems. It is involved in contingency plans for site and other emergencies. Safety staff are ready to respond, if required, to any untoward event involving nuclear material in the United Kingdom and elsewhere. Exercises are carried out periodically to test emergency response requirements.

Battery operated personal air sampler worn by all staff and visitors in areas where radioactive materials are handled. Their usage is fully documented and the results recorded.



Part of the safety records office.

Administration

On-line telephone link to external library database.

The Director of the Atomic Weapons Research Establishment is supported by administrative staff in the Secretary's Department. This is responsible for all administrative aspects of the work at Aldermaston and Foulness and performs the following roles:

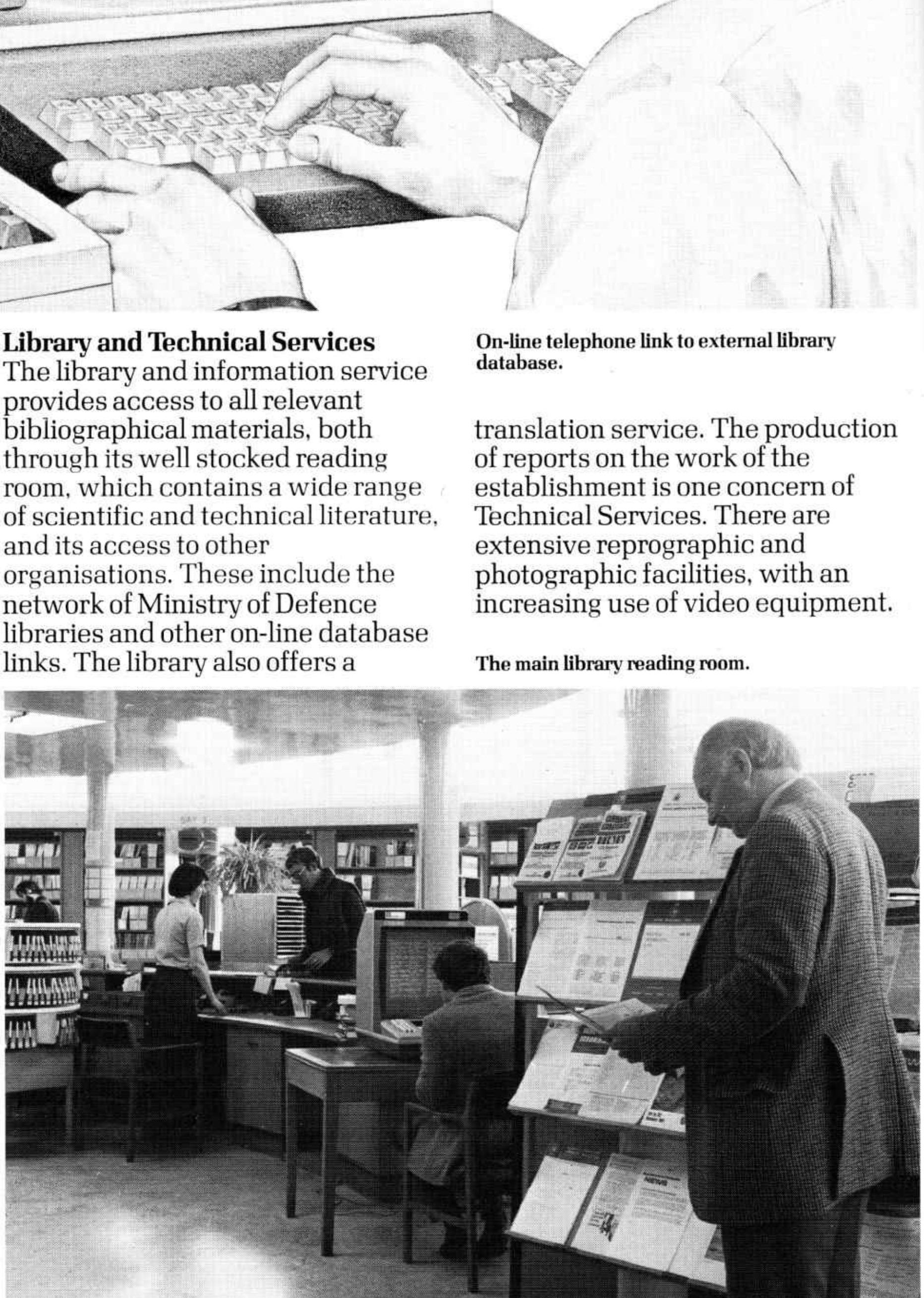
Personnel
To ensure the maintenance of the workforce at approved numbers, grades and quality to perform the establishment's tasks. Help and guidance are given to individuals in their careers and staff are encouraged to attend both internal and external training courses.

Accountancy
To provide effective accountancy and financial control services; the procurement of stores and services within appropriate specifications and timescales; and the storage and issue of goods and materials.

General Administration
To provide administrative support. The principal services are secretarial; support to the safety services, security and fire brigade, transport, communications, and amenity services which includes housing and hostel accommodation.

Library and Technical Services
The library and information service provides access to all relevant bibliographical materials, both through its well stocked reading room, which contains a wide range of scientific and technical literature, and its access to other organisations. These include the network of Ministry of Defence libraries and other on-line database links. The library also offers a translation service. The production of reports on the work of the establishment is one concern of Technical Services. There are extensive reprographic and photographic facilities, with an increasing use of video equipment.

The main library reading room.



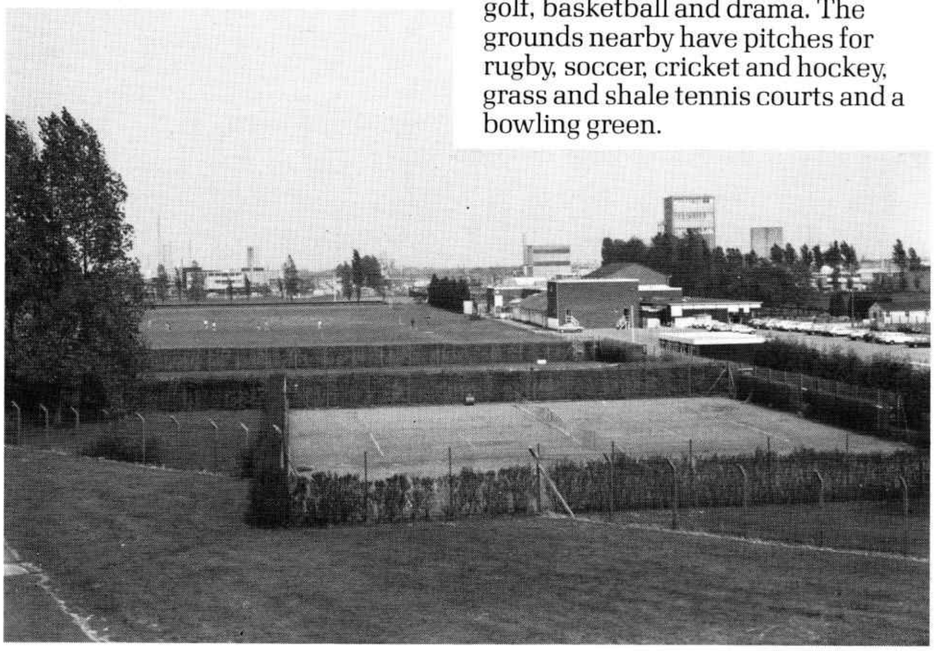
Recreation and Social Facilities

Being situated within easy reach of Reading, Newbury and Basingstoke, Aldermaston offers an interesting choice of shopping facilities and social activity. Reading and Basingstoke both have modern traffic-free shopping precincts and Newbury is a busy market town with many countryside activities, including important associations with 'the turf.' To the North lie the Thames Valley and the Cotswolds and within about two hours by road are the New Forest and the South coast.

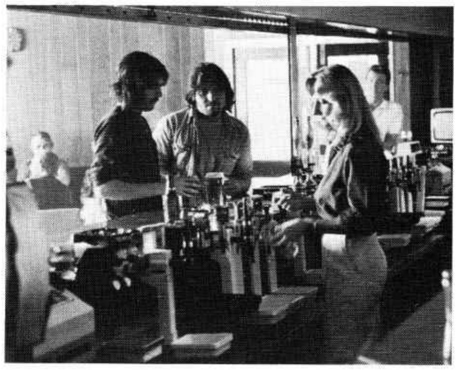
London is easily accessible from Reading via the M4, or by rail to Paddington – a train journey normally taking only 25 minutes. Alternatively, from Basingstoke the M3 also gives fast access to central London, or, by train, Waterloo is 45 minutes distant.

At Aldermaston there is a particularly active Recreational Society with an excellent club house and grounds adjoining the establishment. The Club House facilities include a bar and cafeteria, a well equipped theatre, squash and badminton courts, a gymnasium and a judo room. The Recreational Society also caters for such diverse interests as motoring, angling, yoga, golf, basketball and drama. The grounds nearby have pitches for rugby, soccer, cricket and hockey, grass and shale tennis courts and a bowling green.

As well as being used for basketball and badminton, the well equipped gymnasium is also used for the physical education curriculum of the AWRE apprentices.



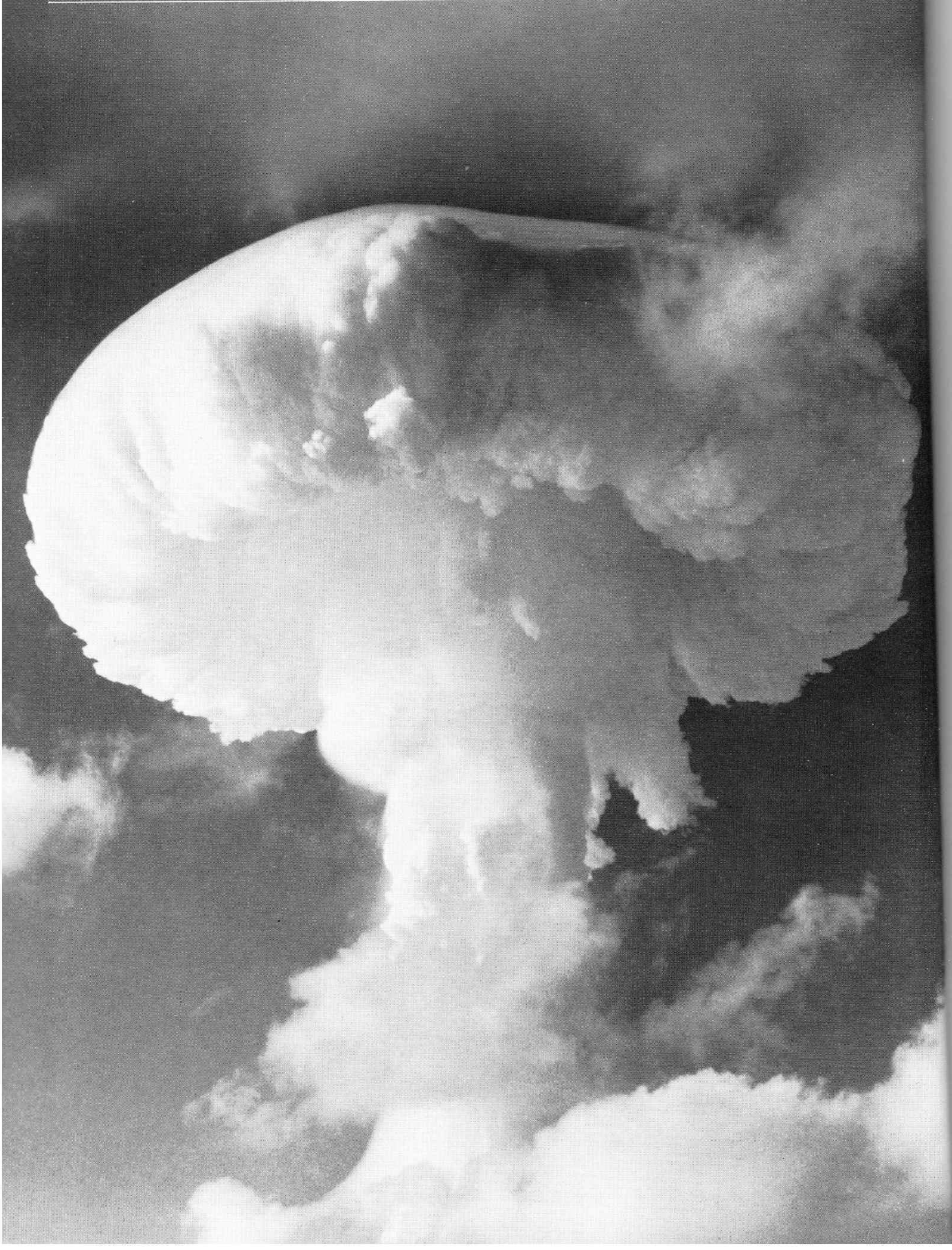
Exterior view of the Recreational Society buildings, tennis courts and the football, hockey and cricket facilities.



The clubroom bar.

AWRE housing estate.

History



The Second World War prevented Britain from pursuing research into nuclear fission domestically, but early in 1947 the Cabinet decided that Britain should develop its own atomic bomb. British atomic energy policy included this urgent need for the production of fissile material for the fabrication and testing of an atomic device, with the longer term aim of exploring the possibility of nuclear power. Dr William Penney (now Lord Penney) was chosen to lead the project. He set up his headquarters at the Armament Research Establishment at Fort Halstead in Kent, using other facilities at Woolwich Arsenal, the military firing range at Shoeburyness and later the Woolwich Common out-station.

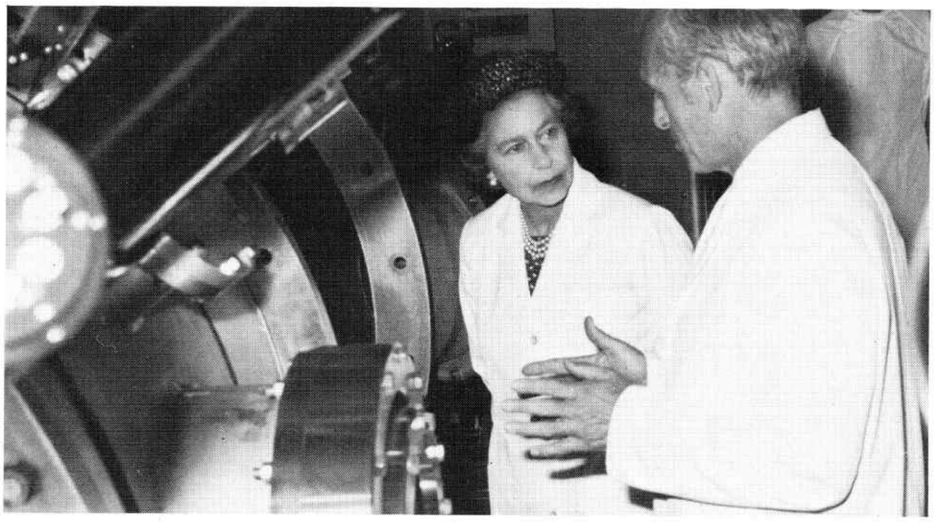
These could not accommodate the specialised buildings and equipment for processing plutonium. A survey of available sites led to the selection of Aldermaston, a World War II airfield, where much of this development work associated with the project would be undertaken. However, the high explosive testing of components was still to be located in Essex, ultimately at Foulness Island, adjacent to Shoeburyness.

At Aldermaston, construction began in April 1950 to an extremely tight schedule. Disused RAF buildings were quickly converted into accommodation, canteen and offices to provide services for the construction force which at its peak numbered 4,000. The specialised processing buildings designed for the investigation and manufacture of components in plutonium metal and conventional high explosives were then built. Hand in hand with this activity the design of the atomic test device proceeded, which led to a successful detonation in October 1952 at the Monte Bello Islands off the north west coast of Australia, (Operation Hurricane). Britain had become the world's third nuclear power, the Soviet Union having detonated its first device in August 1949.

Britain's nuclear programme continued with the successful tests of atomic devices in Australia at Emu Field (near Woomera), Monte Bello again and at Maralinga.

An important milestone was reached with successfully completed trials of Britain's first thermo-nuclear device (hydrogen bomb) in 1957 off Christmas Island in the Pacific. Further tests were carried out of both nuclear and thermo-nuclear devices until 1958. Since then all British tests have been carried out underground at the Nevada test site in America, under the 1958 US/UK Agreement for co-operation in the use of Atomic Energy for Mutual Defence Purposes, which is still in force.

AWRE has always been at the forefront of nuclear weapons technology by the use of the most modern equipment and scientific and engineering methods; in many instances where specialised equipment was not available commercially, the establishment had to design and manufacture its own.



A point is explained to Her Majesty The Queen in front of the HELEN high power laser experimental chamber during the Royal Visit to AWRE in June 1979. The one terawatt neodymium glass laser is an important facility of Radiation Physics.

The fabrication and detonation of nuclear devices is very costly, thus much attention is directed towards simulation of specific parts of the behaviour of nuclear explosions; be it by conventional explosives on inert materials; mathematical studies utilising the powerful and fast CRAY computer; nuclear irradiation by AWRE's specialised reactors or in one of the most recent installations, the one terawatt laser HELEN, which can subject small specimens to temperatures and pressures equivalent to those experienced in a nuclear explosion. The commissioning of this laser was a source of much pleasure to the establishment when Her Majesty The Queen unveiled a plaque commemorating the opening of the facility during her visit to AWRE on 29 June 1979.

Originally AWRE was part of the Ministry of Supply until the formation of the United Kingdom Atomic Energy Authority in 1954 when AWRE establishments at Foulness, Orfordness and Woolwich

Lord Penney

Although it is now over twenty years since Lord Penney left AWRE, no account of the establishment would be complete without some notes about him.

When the decision was taken to develop a UK nuclear deterrent, the then Dr William Penney was a natural choice for this challenging task. He had been among a team of British scientists who had crossed the Atlantic in 1944 to continue nuclear research in association with the American project. He had first-hand experience of the effects of atomic explosions, having been in the observation plane at Nagasaki; visited the devastation at Hiroshima; and being present at the US Bikini Atoll tests of 1946.

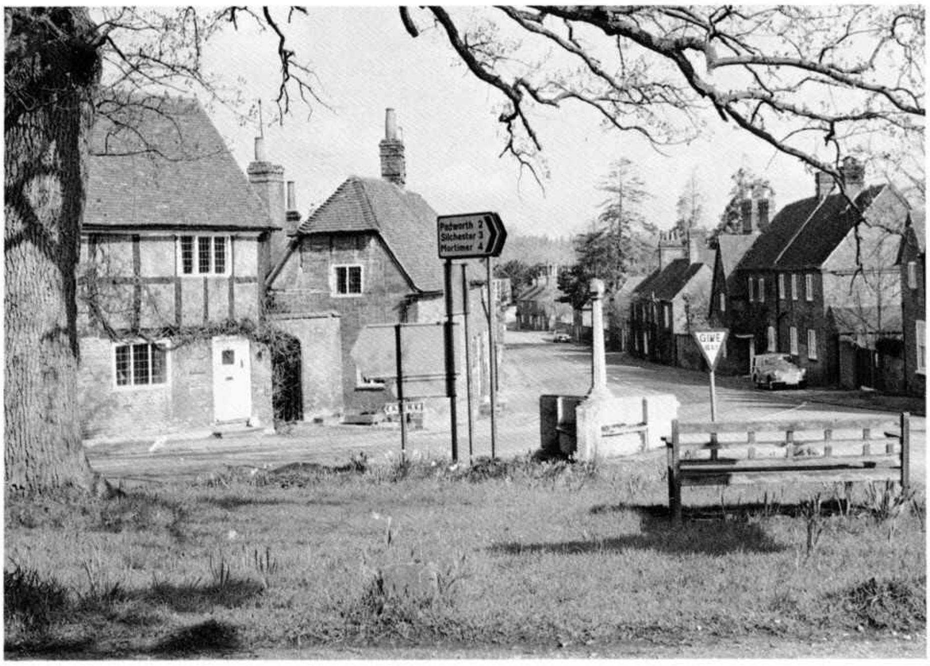
Apart from his nuclear research, Lord Penney had been concerned with many scientific projects, one of which was the study of wave effects on the Mulberry harbours used during the invasion of Europe. In 1946 he was appointed Chief Superintendent of Armaments Research and later spent some time as Scientific Adviser to the British Representative at the United Nations Atomic Energy Commission.

The success of the UK atmospheric test programme, particularly Operation Hurricane completed in such a short space of time, together with the organisation and construction of the facilities at AWRE Aldermaston, is a tribute to his highly respected leadership.

formed its weapons group. Later still in 1973, by Act of Parliament, AWRE transferred to the Ministry of Defence in which it forms part of the Procurement Executive.

The work of the establishment continues today. Although it cannot be outwardly as dramatic and spectacular as in the early years, the importance of its task is not diminished. As long as the defence policy of the United Kingdom requires the provision of a nuclear deterrent, AWRE with its scientific and technical resources will continue its research to produce the most effective warheads for use in Britain's nuclear armaments stockpile. The establishment will also continue to provide maintenance to the warheads already in service.

Aldermaston village.



Aldermaston

When nuclear research settled at Aldermaston rarely in our history can there have been an old, so old or a new, so new.

Mentioned in the Domesday Book as AELDREMANSTONE the estate was claimed by William the Conqueror. For the next 873 years the estate remained intact until the start of the Second World War when it was split up and sold in 394 lots.

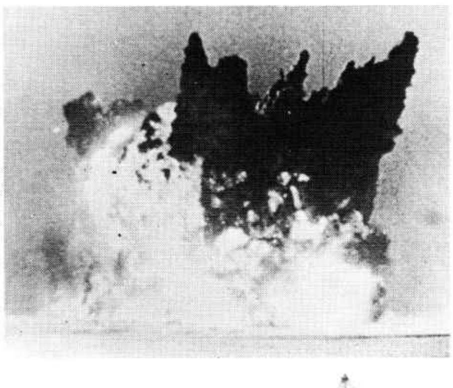
The history of the area dates from Roman times; Grims bank, part of the outer defences of Silchester runs through one corner of the site. Aldermaston saw conflict during the Civil War in 1644. The establishment occupies the site of the World War II air base used by a number of USAAF groups, whose most famous Aldermaston-based exploits were the glider assaults of D-Day and the Arnhem operation. In the post-war years the airfield was used for civil airline pilot training until it was handed over to the Ministry of Works for conversion to its present use in March 1950. Though there have been extensive housing developments to the south and west of the establishment, the village of Aldermaston itself has not been altered, and still retains its rural charm.

Operation Hurricane, 3 October 1952

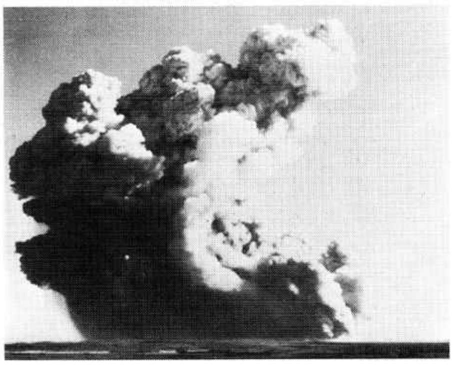
The test firing in the Monte Bello Islands, to the north west of the Australian mainland, was the result of some years of political consideration and exacting scientific research and development. The scientific task was carried out in conjunction with many other research establishments, including Harwell and Windscale, and with British industrial assistance. Finally, the test site was chosen, agreed with the Australian government, and prepared by Royal Engineers with the help of the Royal Australian Air Force. An expedition was then mounted by the Royal Navy to carry the weapon, workshops, laboratories, hospital facilities, stores and more than 100 scientists and supporting personnel half way round the world.

An aircraft carrier, HMS *Campania* was used as flagship and base for the operation and was accompanied by several other British warships. One of these, the frigate HMS *Plym*, carried the device in situ and the vessel was largely vaporised in the searing explosion resulting from the successful detonation of the nuclear device.

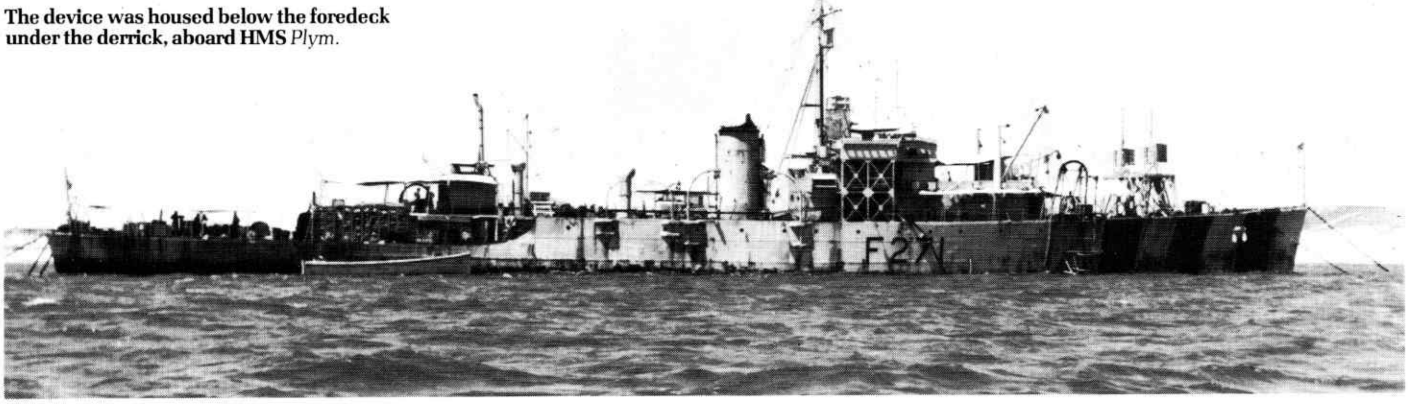
Early moments after the detonation.



The fireball grows. Differential wind layer velocities distorted the symmetry of the cloud.



The device was housed below the foredeck under the derrick, aboard HMS *Plym*.



Career Opportunities

Within its exceptionally broad field of science, technology, health, safety and engineering, AWRE offers many career opportunities at both Aldermaston and Foulness (near Southend-on-Sea, Essex). There is a continuing demand for scientists and engineers in a variety of disciplines. These include project, chemical, mechanical and electronic engineers; health and safety specialists, inorganic and physical chemists, physicists, mathematicians and materials and polymer scientists.

The publication of research papers in open literature is encouraged and staff are also given the opportunity to attend scientific and professional conferences and specialist courses to keep ahead of new techniques and developments. Contacts are maintained with universities, research associations and with industry. Additionally there is close collaboration with the United States.

Other vacancies for employment at the establishment include clerical and administrative posts, supporting staff and Industrial grades. Entry to the AWRE Apprentice Training Scheme and the Experimental Worker Training Scheme are by competitions advertised annually.

How to apply for appointment
Anyone interested in the prospect of working at AWRE should write to the Chief Personnel Officer, AWRE, Aldermaston, Reading RG7 4PR.

Recruitment takes place against advertisements placed in the press, or under special arrangements for the recruitment of graduates from universities. Details of these arrangements are below.

Scientists
By arrangement with university careers services Ministry of Defence representatives visit most UK universities during the Easter term to discuss opportunities with possible applicants. AWRE staff take part in many of these visits and those interested in joining AWRE should ask to see the MOD or AWRE representatives.

Those for whom AWRE may have suitable posts are invited to selection interviews which are usually held in the Easter vacations. Where practicable candidates are given the opportunity to visit laboratories to see work in progress. Travelling expenses are reimbursed and overnight accommodation provided, if necessary.

Engineers
MOD representatives also visit to recruit graduate engineers. Arrangements are administered centrally and all enquiries (quoting reference T/918) should be addressed to:
Ministry of Defence
CM(s) 3 B/a
Lacon House, Theobalds Road
London WC1X 8RV.

Accommodation
Married staff who are recruited to AWRE Aldermaston from beyond normal daily travelling distance may be eligible for rented housing on estates at Reading, Newbury, Basingstoke and close to AWRE. For single staff accommodation is available at Aldermaston in the AWRE hostel which is within easy walking distance of the establishment.

AWRE or public transport bus services are available between most local residential areas and the Aldermaston and Foulness establishments.

Some aspects of the work undertaken in support of the research programme of the Atomic Weapons Research Establishment.

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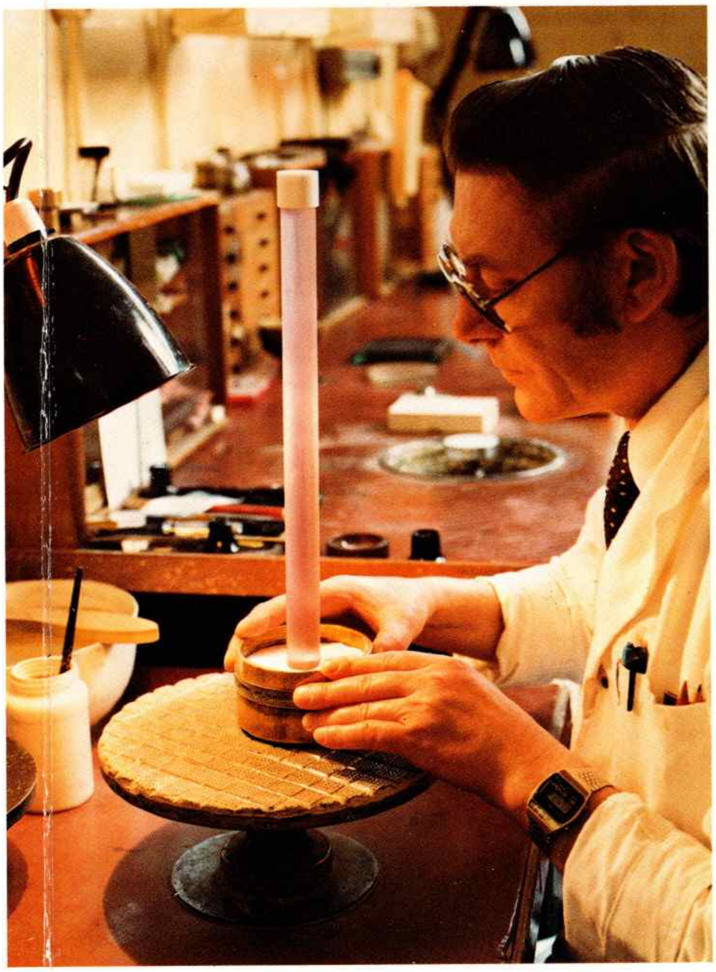

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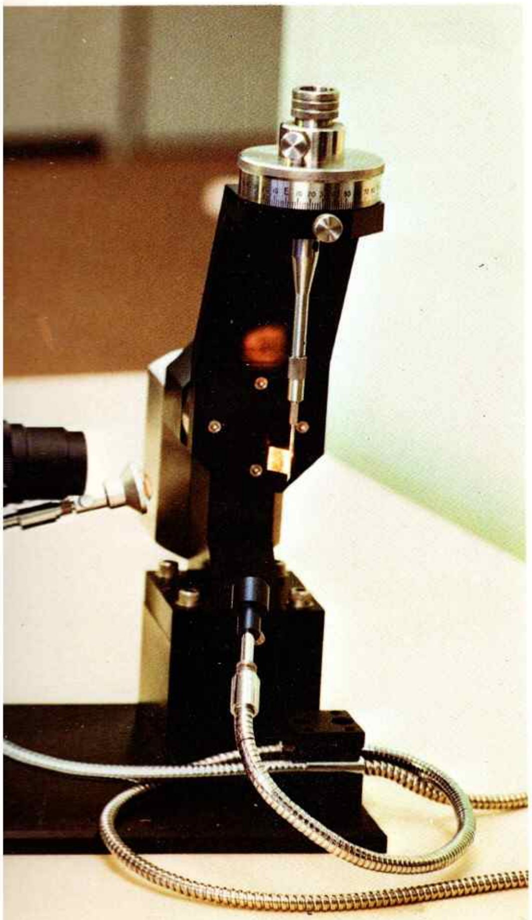
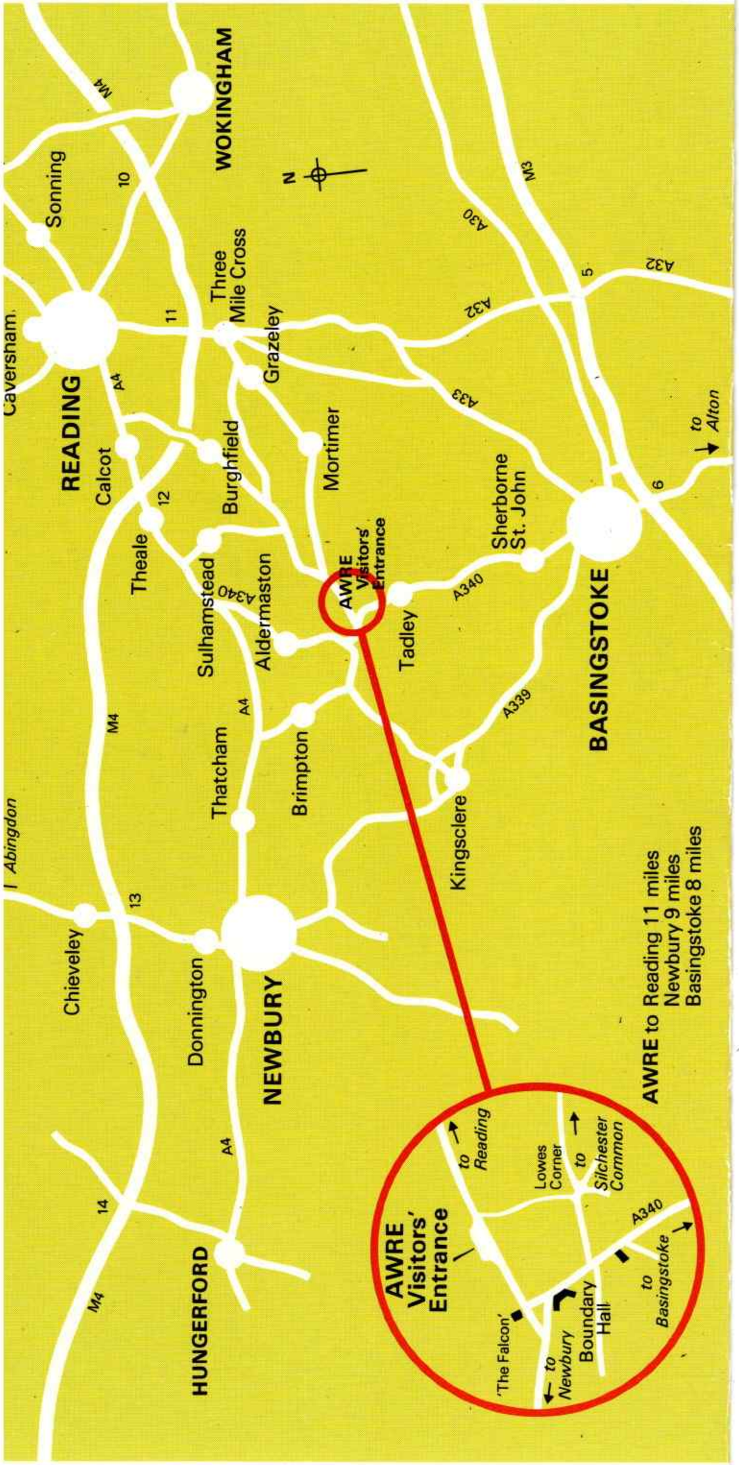


AWRE

Atomic Weapons Research Establishment



TRAVEL

There are frequent train services from London to Reading and Basingstoke. If requested in advance, cars can usually be arranged to meet visitors at these stations. Bus services are also available from Reading and Basingstoke to Tadley.